THE ROYAL CANADIAN INSTITUTE

Digitized by the Internet Archive
in 2010 with funding from
University of Toronto

http://www.archive.org/details/journalfranklini106fran

P
Tech
41

THE

JOURNAL

OF THE

FRANKLIN INSTITUTE,

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS,

PUBLISHED BY

THE INSTITUTE,

Under the Direction of the Committee on Publication.

Vol. CVI.—Nos. 631–636.

THIRD SERIES.

Vol. LXXVI.—JULY TO DECEMBER, 1878.

PHILADELPHIA:

Franklin Institute, No. 15 South Seventh Street.

1878.

621209
21.10.55

T
1
F8
v.106

JOURNAL OF THE FRANKLIN INSTITUTE.

VOL. CVI.

INDEX.

Acoustic Gallery at Bex 346
Air, Effect of the Motion of, within an Auditorium upon its Acoustic Qualities. By W. W. Jacques...... 390
Air, The Determination of Carbonic Acid in, to be Breathed...... 420
Alloys, Sonorousness of...... 200
Astronomical Forecasts. By Pliny E. Chase, LL. D., etc...... 314
Ayres, Brown, B. S. Two New Forms of Bell Telephone...... 343

Baggage-Car Traffic. By M. M. Kirkman...... 355
Baker, J. G. Improvement in Drawing Boards...... 359
Balloon, the Giffard, View from...... 349
Barometric Variations, Daily...... 136
Bayles, James C. House-Drainage and Water-Service, etc...... 69
Bell, J. Snowden, The "Camel" Engine of Ross Winans...... 246
Belts for Transmitting Power, Researches on the Principle of the Employment of. By J. B. Laborde, M. E...... 311
Belts, Leather, On the Driving Power of. By J. H. Cooper...... 308
Birkinbine, Henry P. M. Future Water-Supply of Philadelphia...... 38
Blowers, Koerting...... 425
Boiler Explosions, Safeguards against...... 349
Boiler-Making, Notes on some Points in. By Robt. Briggs, C. E...... 129
Boiler-Plate, The Relation of Ductility to Tensile Strength in...... 415

Book Notices :

- An Elementary Course of Civil Engineering. By J. B. Wheeler...... 354
- Baggage-Car Traffic. By Marshall M. Kirkman...... 355
- Frick's Physical Technics...... 286
- House-Drainage and Water-Service, etc. By James C. Bayles...... 69
- International Exhibition, Reports and Awards of...... 142, 207
- Outlines of Natural Philosophy. By E. J. Houston...... 209
- Principles of Elementary Mechanics. By Prof. DeValson Wood...... 144
- Roadmaster's Assistant and Section-Master's Guide. By Wm. S. Huntington.. 355
- Theory of Transverse Strains and its Application in the Construction of Buildings. By R. G. Hatfield...... 143

Brakes, Railway 193
Brick Walls, Evil Effects from use of Dolomitic Lime in Building. By Henry Pemberton. 52
Bridge, Britannia, Deterioration of the Tubular Girders of 138
Briggs, Robert, C. E. Notes on some Points in Boiler-Making 129
" " " On the Computation of Weights, etc 323
Bronze, Bismuth 282

Canal, Darien 136
Carbonic Acid in Air to be Breathed, The Determination of 420
Carbonic Oxide, Absorption of, by Living Organisms 185
Ceramics, British 199
Chase, Pliny E., LL. D., etc. Astronomical Forecasts 314
" " Prediction Confirmed 286
" " Another Verification of Prediction 353
Chemical Arts, On the Development of, etc. By Dr. A. W. Hofmann 121, 165, 239
Civil Engineering, An Elementary Course of. By J. B. Wheeler 351
Coal-Dust The part played by, in producing Explosions in Mines 344
Cobalt Plating 201
Colors, Complimentary 67
Combination by Volumes 283
Cooper, J. H. The Driving Power of Leather Belts 308
" " Zimmerman's Steam-Engine 254
Copper and Copper Alloys, Hardening of 67
Cow-Tree, Milk of the 346

Diamonds, Artificial 349
Diaphragm, Maiche's 133
Diffusion, Work of 281
Dolomitic Lime, Evil Effects from the Use of, in Building Brick Walls. By Henry Pemberton 52
Draper, Henry, M. D. The Total Solar Eclipse of July 29th, 1878 217
Drawing Boards, Improvement in. By J. G. Baker 359
Drawings, Photographic Process for Reproducing 359
Dumont, James A. Tests of Boiler Iron in their relation to the Steamboat Law 411
DuPuy, Chas. M. On a Direct Process of Making Wrought-Iron and Steel 404
Dudley, C. B., Ph. D. The Chemical Composition and Physical Properties of Steel Rails. 361
Dynamo-Electric Machine, for Producing Alternating Currents, The Gramme 181

Earth Currents 65
Echoes, Aerial. By Joseph Henry 189
Edison's Micro-Tasimeter 173
Electric Explosions, Interference of 137
" Fuse in Heavy Cannon 139
" Light in Farming 428
" Machine for producing Alternating Currents, The Gramme 181
Electricity, Agricultural use of 202
Electro-Metallurgy, Cobalt in 352
Electric Elongation, Non-existence of 282
Electrical Lamp, with Continuous Circuit for Working in the Open Air. By Emile Reynier. Translated by P. Pistor, M.E 275
Electricity and Heat, Propagation of 64

Electric Lighting, A New System of. By Profs. Elihu Thomson and Edwin J. Houston.. 251
" Lamp, New 67
" Lighting 421
" Lamp, New. By Profs. Elihu Thomson and Edwin J. Houston 252
Element, A New 200
Elementary Mechanics, Principles of. By Prof. DeValson Wood 144
Engine, The "Camel," of Ross Winans. By J. Snowden Bell 246
Engineers' Club of Philadelphia 141
Errata. Prof. Jas. Henry 72
Explosions, Electric, Interference of 137
Explosions in Mines, The part played by Coal-Dust in Producing 344
Expansion of Steam in the Steam-Engine. By B. F. Isherwood, U. S. N 1, 73
" New Laws of 424

Flames, Temperature of 205
Flow of Solids, Further Application of the. By M. Henri Tresca 263, 326, 396
Franklin Institute. Donations to the Library 213
" " Proceedings of 70, 287, 357, 429
" " Lectures at 356
" " Secretary's Report. The Microphone 57
" " Resolutions of the Board of Managers on the Decease of Bloomfield H. Moore 144
Frizell, J. P. The Problem of Perforated Pipes as Applied to Sprinklers 84
" Power of Running Water to Hold Matters in Suspension 177
Friction, Coefficients of, New Determinations of. By R. H. Thurston, A. M., C.E 289
Frick's Physical Technics 286
Fuse, Electric, and Heavy Cannon 139

Gallium, The Equivalent of 65
Gaseous Combustibility, Limits of 67
Gas-Tubes, Tale-Telling 64
Geissler Tubes, Discharges in 137
Geodetic Survey of the State 432
Geological Progress 284
Girders, Tubular, of the Britannic Bridge, Deterioration of 138
Glass, Hard, Objections to 65
Glass, Ancient, Composition of 350
Globe, The Lyons 51
Gun-Cotton, Spectrum of 200

Harmonic Striæ 350
Hatfield, R. G. Theory of Transverse Strains, and its Application to the Construction of Buildings 148
Haupt, L. M., C. E On the use of the Heliotrope in Geodetic Surveys 416
Heat and Electricity, Propagation of 64
Heat, Retention of 344
" Solar, Economic Value of 138
Heating Wheel Tires 285
Heliotrope in Geodetic Surveys, On the use of. By L. M. Haupt, C. E 416
Henry, Joseph. Aerial Echoes 189
Herschel, Clemens, C. and H. Eng. Erosive and Abrading Power of Water, etc. 26
" " C. E. Note on the Power of Water to hold Matter in Suspension.... 321

Hofmann, Dr. A. W. On the Development of the Chemical Arts, etc.......... 121, 165, 239
Houston, E. J. Outlines of Natural Philosophy........ 209
" " The Telephone Relay........ 206
" " The Microphone Relay........ 60
" " A New System of Electric Lighting........ 251
" " A New Electric Lamp........ 252
House Drainage and Water-Service in Cities, etc. By James C. Bayles........ 69
Huntington, Wm. S. The Roadmaster's Assistant, and Section-Master's Guide........ 355
Hydrogen, Liquefaction and Solidification of, etc. By M. Raoul Pictet..13, 101, 157, 231, 334

International Exhibition, 1876, Reports and Awards of........ 112, 207
Iron and Steel, Phosphorus in........ 64
" " " On a Direct Process of Making. By Chas. M. Du Puy........ 401
" Early use of........ 283
" Boiler, Tests of, in their relations to Steamboat Law. By Jas. A. Dumont........ 111
" Magnetic........ 133
" Wrought, The Direct Process of Making........ 110
Isherwood, B. F., U. S. N. Economic Vaporization of Water, and expansion of Steam. 145, 220
" " " Expansion of Steam in the Steam-Engine........ 1, 73

Jablochkoff Candle, Automatic Switch for........ 419
Jones, Washington. Description of a Montgolfier Ram, etc........ 186
Jacques, W. W. Effect of the Motion of the Air within an Auditorium, upon its Acoustic Qualities........ 390

Kennedy's Spring Piston........ 132
Kirkman, Marshall M. Baggage-Car Traffic........ 355

Laborde, J. B., M. E. Researches on the Principle of the Employment of Belts for Transmitting Power........ 311
Laminated Metals, Adhesion of........ 348
Leather Belts, The Driving Power of. By J. H. Cooper........ 308
Lectures at the Franklin Institute........ 356
Levels, Daily Shifting of........ 427
Light, Influence of, upon Cement........ 64
Lights, Signal, Inextinguishable........ 140
Light, Terrestrial Influence of, on Polarization........ 200
" Zodiacal and Sun-Spots........ 281
Lighting, Submarine........ 66
" Electric........ 421
Lightning Rods, Dimensions of........ 134
Liquefaction of Oxygen, Solidification of Hydrogen, etc. By R. Pictet. Translated by P. Pistor, M. E........ 13, 101, 157, 231, 334

Magnet, Large........ 349
Magnetism and Sun-Spots........ 83
Magnetism, Internal........ 134
Magnetism, Terrestrial, Variations of........ 282
Magnetic Meridian, Telephonic Determination of the........ 349
Matter and Æther, Vibrations of........ 94
Mercury, The Transit of........ 66

Meteorology, Electric........ 136
Mercury, The Transit of, at Rio Janeiro........ 421
Micro-Tasimeter. Edison's........ 173
Microphone........ 63
Microphonic Anticipations........ 270
Microphone, New Form of. By Dr. Isaac Norris, Jr........ 360, 431
" Pocket........ 426
" Relay, The. By Profs. E. J. Houston and Elihu Thomson........ 60
" Stethoscopic........ 204, 431
" The........ 57
Mines, Almaden........ 199
Molecular Rotation, Heat of........ 250
Montgolfier Ram, Description of, etc. By Washington Jones........ 186
Moore, B. H., Memoir of........ 210
" Bloomfield, Memorial Fund........ 288
" " H., Resolutions of the Board of Managers of the Franklin Institute on the Decease of........ 114
Morton, Henry, Ph. D. A Singing Telephone, etc........ 112
Mosandrum; a New Element........ 284
Music and Acoustics........ 68

Natural Philosophy, Outlines of. By E. J. Houston........ 209
Nervous Velocity, Acceleration of, by the Will........ 345
Niello........ 134
Nitrification by Organized Ferments........ 199
Norris, Dr. Isaac, Jr. A New Form of Microphone........ 360
" " " " " " " Adapted to the Stethoscope........ 431

Organette, The........ 431
Oxygen, Liquefaction of, etc. By M. Raoul Pictet........13, 101, 157, 231, 334
" Maximum Tension of the Vapors of........ 164
Ozone........ 284

Paper, Official........ 133
Paper-Sizing........ 425
Pemberton, Henry. Evil Effects from the Use of Dolimitic Lime, in Building Brick Walls........ 52
Perforated Pipes, The Problem of, as applied to Sprinklers. By J. P. Frizell, C. E..... 84
Petroleum, Solidification of........ 427
Philosophy, Natural Outlines of. By Prof. E. J. Houston........ 209
Phonic Wheel........ 426
Phonograph Diaphragm........ 203
Phosphorus in Iron and Steel........ 64
Physical Technics, Frick's........ 286
Pictet, R. Liquefaction of Oxygen, Liquefaction and Solidification of Hydrogen, etc. Translated by P. Pistor, M. E........ 13, 101, 157, 231, 334
Pipes, Perforated, The Problem of, as applied to Sprinklers. By J. P. Frizell, C.E...... 84
Piston, Kennedy's Spring........ 132
Pistor, P., M.E. Electrical Lamp, with Continuous Circuit, for Working in the Open Air. 275
" " Liquefaction of Oxygen, Liquefaction and Solidification of Hydrogen. 13, 101, 157, 231, 334
Platinum Plating........ 348
Postal Items........ 428

Powers, Thomas H., Decease of ... 432
Power, Transmission of ... 135
Prediction Confirmed. By Pliny E. Chase ... 286
" Another Verification of. By Pliny E. Chase ... 353
Projection, Gnomonic ... 192
Projectiles, Steel and Wrought-Iron ... 141
Puddling Furnaces, Hot Air and Steam in ... 282

Rails, Steel, The Chemical Composition and Physical Properties of. By C. B. Dudley, Ph. D ... 361
" of Uniform Length, A New Method for Cutting ... 202
" Iron and Steel, Comparative Wear of ... 350
Railway Brakes ... 193
Ram, A Montgolfier. By Washington Jones ... 186
Reynier, Emile. Electrical Lamp, with Continuous Circuit, for Working in the Open Air. 275
Roadmaster's Assistant and Section-Master's Guide. By Wm. S. Huntington ... 355
Rocks, Internal Heat of ... 198
Rosenberg, Emile, M. D. A New Method of Reduction for Diffraction Spectra Observations ... 95

Screw Steamers, Steering of ... 258
Sensations, Luminous and Chromatic ... 201
Signals for Daltonists ... 427
Skepticism, Scientific ... 425
Solar Eclipse, The Total, of July 29th, 1878. By Prof. Henry Draper, M. D ... 217
Sound-Waves, Transmission of, by the Telephone ... 353
Sound, The Various Methods of Determining the Velocity of ... 271
Specific Gravities, A Novel and Simple Method of Taking ... 423
Specula, Glass, A New Method of Grinding. By Prof. Elihu Thomson ... 117
Spectra Observations, Diffraction, A New Method of Reduction for. By Emil Rosenberg. 95
Spectroscopic Temperatures ... 348
Sprinklers, The Problem of Peforated Pipes as applied to. By J. P. Frizell, C. E ... 84
St. Gothard Tunnel ... 68, 418
Steam-Engine, Zimmerman's. By J. H. Cooper ... 254
" Expansion of, and Economic Vaporization of Water. By B. F. Isherwood, U. S. N ... 145, 220
" Expansion of, in the Steam Engine. By B. F. Isherwood, U. S. N ... 1, 73
Steamships, Velocity of ... 280
Steel, Homogeneous Cast ... 135
" Production of ... 345
Stone-Dressing Machine, A New ... 351
Strains, Transverse, Theory of, etc. By R. G. Hatfield ... 143
Stringed Instruments, Defective Notes of ... 65
Sun Spots and Magnetism ... 83
" and Zodiacal Light ... 281
Switch for Jablochkoff Candle, Automatic ... 419

Tables of Weights, etc., On the Computation of. By Robt. Briggs, C. E ... 323
Tasimeter and Magnetization ... 205
Telephone without a Diaphragm ... 285
Telephone, Bell, Two new forms of. By Brown Ayres, B. S ... 343
" Diaphragm, New ... 135
" Imperfections of ... 200

Telephone Relay, The. By Prof. E. J. Houston........ 206
" Singing, etc. By Henry Morton, Ph. D........ 112
" Submarine........ 68
" Transmission of Sound-Waves, by the........ 353
Telephonic Transmitter, New........ 426
Temperature, Ratio of Draft to........ 66
Temperatures, Spectroscopic........ 348
Tempests, Movement of........ 156
" Origin and Periodicity of........ 283
Terrestrial Constants........ 202
Thermometer, Optical........ 428
Thomson, Elihu. A New Method of Grinding Glass Specula........ 117
" " A New System of Electric Lighting........ 251
" " A New Electric Lamp........ 252
" " The Microphone Relay........ 60
Thurston, R. H., A. M., C. E. New Determinations of the Coefficients of Friction........ 289
Tresca, Henri. On Further Application of the Flow of Solids........ 263, 326, 396
Tunnel, St. Gothard........ 68, 418

Varnish, Amber........ 424
Vulcan, The Planet........ 281
" " " Discovery of........ 204

Water, Economic Vaporization of, and Expansion of Steam. By B. F. Isherwood, U. S. N........ 145, 220
Water Molecules, Mean Distance of........ 427
" Note on the Power of, to hold Matter in Suspension. By Clemens Herschel, C.E. 321
" Running, On the Power of, to hold Matters in Suspension. By J. B. Frizell, C.E. 177
" Supply, of Phila., Future. By Henry P. M. Birkinbine........ 38
" The Erosive and Abrading Power of. By Clemens Herschel, C. and H. Eng........ 26
Waters of the Danube and the Aach........ 347
Weight, Variations of........ 198
Wheeler, J. B. An Elementary Course of Civil Engineering........ 354
Whirlwinds, Formation of........ 135
Wire-Rope Transportation........ 278
Wood, Prof. DeValson. Principles of Elementary Mechanics........ 144
Wood-Staining........ 425

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CVI. JULY, 1878. No. 1.

The Franklin Institute is not responsible, as a body, for the statements and opinions advanced by contributors to the JOURNAL.

EXPANSION OF STEAM IN THE STEAM-ENGINE.

An Investigation of the Experiments made with the Screw Machinery of the French Naval Steamer CHER *to Determine the Economic Efficiencies of Different Measures of Expansion for Steam.*

By Chief Engineer ISHERWOOD, U. S. Navy.

In the month of February, 1866, the experiments whose data and results are given in the following table, were made with the machinery of the French Naval Steamer *Cher;* the vessel being held stationary in the basin of the Naval Arsenal at Cherbourg, while the machinery was operated; the power developed by the engine being applied to the displacement of water by the screw.

These experiments were made by very distinguished engineers of the French Navy; they were conducted by Messrs. Joessel and Thibaudier, under the supervision of Mr. Moll, and had for their main object the determination of the relative economic efficiencies of the different measures of expansion with which the steam was used under the experimental conditions; they were undertaken as a test of the results of the well known experiments made by the writer for the same purpose with the paddle-wheel machinery of the United States Steamer *Michigan*, at Erie, in 1860 and 1861, the vessel in this case having been also held stationary at the dock while the machinery was in operation.

The writer's experiments on this subject preceded, by a number of years, all others, and he was the first to show the quickly reached limit of the economic gain due to increasing measures of expansion, and the causes determining that limit, the principal of which was the rapidly increasing cylinder condensation which accompanied the increasing measures of expansion. He first showed that steam, instead of being a gas and governed by the ideal laws of such a substance, was the most unstable of vapors; that the abstract law of Mariotte had a limited concrete application to it, and that its economy was mainly controlled by the physical conditions of its use, such as the heat-absorbing, and heat-imparting power of the iron cylinder subject to great variations of temperature on its inner surface during a double stroke of the piston, and also of the back pressure against the piston of the uncondensed vapor, when the problem was conditioned for equal initial cylinder pressure, speed of piston and power developed, the space displacement of the piston per stroke being necessarily variable with the measure of expansion employed for the steam, larger measures of expansion requiring larger cylinders. These conditions gave for the increasing measures of expansion, a decreasing mean pressure per square inch of piston, while the back pressure continuing constant per square inch of piston, became a larger and larger proportion of the mean pressure (measured from zero) as the measure of expansion became greater and greater. It was obviously only necessary to carry the expansion far enough with any constant back pressure, to make the latter nearly balance the mean pressure, and the external work of the engine would be reduced to nothing, its whole power being employed in overcoming its friction and the back pressure against its piston. The back pressure, therefore, reduced the commercial economy of the steam more with the greater than with the less measures of expansion. The same observation applies to the pressure required to overcome the friction of the engine, *per se*, that is, to work it unloaded. This pressure per square inch of piston, like the back pressure, is nearly constant, and it is only the remainder of the mean pressure above zero after the subtraction of both, that is commercially useful in doing external work. The friction pressure, therefore, still further limits the measure of beneficial expansion.

From the foregoing it is obvious that a proper comparison of the commercial economy due to various measures of expansion, requires the *net* power developed by the engine in each case to be compared with the cost of producing it in fuel, or more accurately with the number of units of heat in the boiler steam required to produce it, the net power being the power due to the mean pressure on the piston above zero, less the back pressure and the friction pressure.

The waste spaces in the clearance of the piston, and in the steam passages, also limit the measure of beneficial expansion; first, by the heat-absorbing and heat-imparting nature of the inner metallic surfaces, for they experience the same changes of temperature as the inner surface of the cylinder; second, by the steam required to fill these waste spaces, which is greater, proportionally to power produced, with larger than with smaller measures of expansion.

The combined effect of all the foregoing causes, under the conditions stated, is found experimentally to limit the commercially beneficial measure of expansion for saturated steam of not more than 25 pounds pressure per square inch above the atmosphere, used in condensing non-compound engines without steam-jacketed cylinders, to what is due to cutting it off when the piston has completed 0·6 of the stroke of its piston, being equivalent to an expansion of about one and a half times. With higher steam pressure, with superheated steam and with steam-jacketing, the foregoing causes become proportionally less, and the beneficial measure of expansion increases; but it is very doubtful if any gain can be obtained with practicable pressures and superheating beyond what is given by an expansion of about three times, and the difference in the economic results between expansions of one and a half and three times, is not large.

The writer also first showed that when steam was used expansively, the cylinder acted both as a condenser and a boiler: as a condenser during the portion of the stroke of the piston preceding the closing of the cut off or expansion valve, and as a boiler during the remaining portion of the stroke; part of the water of condensation deposited on the cylinder surfaces during the first portion of the stroke, vaporizing during the last portion by its contained heat and the heat of the metal of the cylinder under the continuously decreasing pressures due to the continuous expansion of the steam. Whatever water of condensation remained when the piston reached the end of its steam-stroke, vaporized during its exhaust-stroke under the still lower condenser pressure, so that when the steam-valve again opened to admit steam from the boiler to the cylinder, the whole of the steam which had been condensed in the latter had been re-evaporated and passed over into the condenser.

The writer not only stated these facts qualitatively, but gave, by means of his experiments, very exact quantitative measures of the per centum of the steam evaporated in the boilers condensed in the cylinders prior to the closing of the expansion-valve, and the per centum of the steam vaporized in the boiler present in the cylinder at the end of the stroke of the piston; the difference between the two per centums showing the amount of the re-vaporization after the closing of the expansion-valve above any condensation which might have occurred during the expansion portion of the stroke.

It would seem that no great difficulty should have been found in accepting the experimental facts first published by the writer in this connection, particularly as they admitted of easy confirmation by a few rough trials with almost any engine: nor in perceiving that the discrepancies between them and what ought to have been obtained according to the ideal law of Mariotte, were due to the causes he discovered; yet the facts and the deductions were violently impugned in both America and Europe, but apparently with more of wounded vanity and alarmed interest than of philosophic spirit; they are now, however, accepted almost everywhere, and nowhere more completely than in France, whose steam engineers as a class are incomparably superior in scientific education to those of other nations. The problem is purely an experimental one, and does not require for its solution either mathematics or physical science, though both may be invoked to explain the solution after it is obtained. In this manner the problem was treated by the writer who put the question directly to nature under the conditions of ordinary practice, and received an infallible reply in the experimental results. The French engineers followed exactly his method, and obtained the same answer, as will be seen by the conformity of their results in the following table. Nor has the writer ever found different results, either in his own very numerous and carefully conducted experiments on a large scale, or in those of others.

In order that the scale on which the experiments of the *Cher* were conducted may be understood, the following dimensions of the machinery are given:

ENGINE.

There is one compound back action engine, of the kind known as the Depuy de Lôme type. It consists of three cylinders of equal diameter and stroke of piston, placed horizontally side by side; the steam from the boiler being admitted into only the middle cylinder, where it is cut off by lap on the main valve when the piston has completed 0·88 of its stroke. From the middle cylinder the steam is expanded simultaneously into the two end cylinders, where it is cut off by lap on the main valve when 0·78 of the stroke of the piston is completed. The steam is not cushioned in any of the cylinders. From each end cylinder the steam is exhausted into a surface condenser placed immediately opposite to it, and the two condensers are connected by a pipe at their top, so that the vacuum is the same in both, and the condensing surface in both is available for the steam from each end cylinder. These two cylinders are connected upon the same shaft by cranks at an angle of 90 degrees; and the middle cylinder is connected to this shaft at an angle bisecting 90 degrees, its crank making an angle of 135 degrees with those of the end cylinders. The cylinders are not steam-jacketed, except in so far as the passage is concerned by which the boiler steam is carried over each end cylinder to the middle cylinder. There is no separate cut-off valve on the end cylinders, but there was one on the middle cylinder arranged to close when the piston of that cylinder had completed the 0·4, 0·5 and 0·6 of its stroke.

The cylinder-valves were worked from cranks on a small shaft, placed immediately over the crank-shaft and receiving motion from it through spur-gearing of equal diameter, consequently the stroke of the valves could not be varied.

Each end cylinder worked a horizontal double acting air-pump and circulating-pump for its own condenser.

Number of cylinders, ...	3·
Diameter of each cylinder, ...	43·3079 in.
Stroke of the piston of each cylinder, . .	1·64045 ft.
Net area of each piston, exclusive of areas of rods,	1460·500 sq. in.

Space displacement of each piston per stroke, exclusive of rods,	16·638 cu. ft.
Aggregate condensing surface in both condensers,	1266·098 sq. ft.

BOILERS.

There are two boilers with horizontal return-tubes. Each boiler contains three furnaces of the same dimensions. Both boilers discharge their gases of combustion into one chimney, the base of which is occupied by a steam superheater composed of plates.

Number of furnaces, ...	6·
Aggregate area of grate furnace, ...	87·514 sq. ft.
Aggregate area of water-heating surface, calculated for the outside circumference of the tubes,	2249·525 sq. ft.
Aggregate cross area of the tubes for draught, .	14·586 sq. ft.
Area of steam superheating surface, . . .	212·703 sq. ft.
Square feet of water-heating surface per square foot of grate surface,	25·705
Square feet of steam superheating surface per square foot of grate surface,	2·430
Square feet of grate surface per square foot of cross area of tubes,	6·000

SCREW.

There is one Mangin screw with two pairs of blades, one pair being directly behind the other. The pitch expands gradually from the forward to the after edge of each blade. When the blades are viewed in projection on a plane parallel to the axis of the screw, their edges taper towards each other from the hub by straight lines, the length of the screw being greater at the hub than at the periphery. The central line of each blade is at right angles to the axis.

Diameter of the screw, ...	11·483	feet.
Diameter of the hub, ...	1·750	"
Initial pitch, ...	12·139	"
Mean pitch in function of surface alone, . .	13·452	"
Final pitch, ...	14·765	"
Number of *pairs* of blades, ...	2·	
Length of the screw in the direction of the axis at the hub,	1·8833	"
Length of the screw in the direction of the axis, at half the radius, ...	1·3452	"
Length of the screw in the direction of the axis, at the periphery, ...	0·8071	"
Fraction used of the pitch at the hub, . .	0·280	"

Fraction used of the pitch at half the radius, .	0·200	feet.
Fraction used of the pitch at the periphery, .	0·120	“
Mean fraction used of the pitch in function of surface and of the propelling efficiency of the surface,	0·162	“
Helicoidal area of the screw-blades, . . .	23·191	sq. “
Projected area of the screw-blades on a plane at right angles to axis, ...	18·460	“ “

Experiments made on the Screw Machinery of the Cher *with the vessel held stationary at the dock, to ascertain the relative economic efficiencies of superheated steam used with different measures of expansion and without throttling; used with different boiler pressures, the same measure of expansion and without throttling; and used with throttling. Also, to ascertain the economic efficiency of saturated steam used with scarcely any expansion in a simple two cylinder engine formed by omitting the third or high pressure cylinder from the compound engine of the* Cher. *Likewise to ascertain the economic vaporization by the boiler.*

The data and results of the experiments made for the above purposes will be found in the following table, each column of which is appropriated to a single experiment and is lettered for facility of reference; the lines containing the quantities are grouped and numbered for the same reason. This table has the writer's own arrangement, but it contains every fact given in the original data.

Experiments A, B, C and D were made with superheated steam of the constant boiler pressure 27·53 pounds per square inch above the atmosphere, expanded 2·26, 3·21, 3·78 and 4·59 times, corresponding to cutting it off in the cylinders of a simple engine having the same waste spaces in clearance and steam passage, at 0·41, 0·27, 0·22 and 0·17 of the stroke of the piston from the commencement. The steam was used with a wide throttle and an average superheating of 14·1 degrees Fahrenheit on entering the valve chest.

Experiments E, F, G and H were duplicates of experiments A, B, C and D, respectively, except that they were made with steam of less boiler pressure and more superheated; the constant boiler pressure being 19·52 pounds per square inch above the atmosphere, and the superheating averaging 21·8 degrees Fahrenheit.

Experiments A to H, both inclusive, were made for the purpose of ascertaining the relative economic efficiencies of the different measures of expansion with which the steam was used; and the extent to which that economy was influenced for each measure of expansion by the difference of the boiler pressure in the two sets of experiments otherwise the same.

Experiments I, J, K and L were made to ascertain the relative economic efficiencies of superheated steam of different boiler pressures used with the same measure of expansion and without throttling. These pressures varied from 27·29 to 12·19 pounds per square inch above the atmosphere; the measure of expansion was 2·26 times; and the superheating varied from 11·5 to 30·3 degrees Fahrenheit, increasing as the boiler pressure decreased. Experiment I is experiment A, and experiment K is experiment E; experiments A and E being repeated in columns I and K for the purpose of completing the series in proper sequence.

Experiments M and N were made to ascertain the effect of throttling on the economic efficiency of the steam which was superheated, respectively, 19·9 and 16·3 degrees Fahrenheit, expended 2·26 times, and had the same boiler pressure of 27·87 pounds per square inch. In experiment M the throttle valve was 0·30 open, and in experiment N, 0·25.

Experiment O was made to ascertain the economic efficiency of saturated steam admitted to only the end cylinders and expanded therein 1·26 times, that being the greatest measure of expansion which could be obtained in these cylinders, as they had no expansion valves, and could cut off by the steam-lap alone on their main steam-valves. The middle cylinder was not in use, its connecting rod was disconnected from the crank-pin, its main steam-valve was removed from the valve-chest, and its steam-ports were securely closed, the boiler steam passed through its exhaust port to the valve-chests of the end cylinders. Although the boiler steam in experiment O was superheated 12·5 degrees Fahrenheit when entering the valve-chest of the middle cylinder, it had only the temperature due to its pressure as saturated steam in the reservoir, and it consequently entered the valve-chests of the cylinders without superheating.

The following are the quantities on the different numbered lines, and the manner in which they were obtained:

Line 1 contains the letters designating the experiments; and line 2 contains the date on which they were made.

Lines 3, 4 and 5 give the boiler power in use. They contain respectively the number of furnaces, and the square feet of grate surface and of water-heating surface in use. The steam superheating surface in use was 212·703 square feet in all the experiments.

Lines 6, 7 and 8 contain respectively the steam pressures in the boilers, in the steam-pipe near the middle cylinder just in advance of the throttle-valve, and in the reservoir between the middle and end cylinders, in pounds per square inch above the atmosphere.

Line 9 shows the proportion of the throttle-valve open. It was wide open in all the experiments except M and N.

Line 10 contains the fraction of the stroke of the piston of the middle cylinder completed when the steam was cut off. In experiment O, this point of cutting off is for the end cylinders, the middle cylinder being out of use.

Line 11 shows the number of times the steam was expanded during each experiment, and is inclusive of the effect of the waste spaces in the clearances of the pistons and in the steam passages.

Line 12 contains the number of double strokes made per minute by the pistons.

Line 13 contains the temperature of the steam in the steam-pipe near the middle cylinder due to its pressure as saturated steam, while line 14 contains its actual temperature by observation as indicated by a thermometer immersed in the pipe. The difference of the quantities on lines 13 and 14 is contained in line 15, which shows the superheating in degrees Fahrenheit possessed by the steam when entering the valve-chest of the middle cylinder.

Line 16 contains the temperature of the steam in the reservoir between the middle and end cylinders due to its pressure as saturated steam, and line 17 contains its actual temperature by observation, as indicated by a thermometer immersed in the reservoir. These quantities are exactly the same, and show, as expressed on line 18, that all the superheating had been lost in the middle cylinder, the steam entering the end cylinders being saturated.

Line 19 contains the *conjectured* temperature of the feed-water. In the original data of these experiments, this temperature is not noted; but it could have been only a few degrees, if any, different from what is given on line 19.

Line 20 contains the number of pounds of feed-water pumped into the boilers per hour. It was measured in six of the vessel's tanks placed on the deck, three on each side, and connected by hose to the suction-valve chests of the two feed-pumps. The aggregate capacity of the six tanks was 700 cubic feet. The quantity of water to be used in any experiment was fixed in advance, and the time of using it was ascertained by observation. The experiments were always ended with the tanks just empty, so as to avoid any uncertainty in the measurement of fractional parts. The water for the tanks was obtained from the Arsenal through a hose, and had the temperature of the atmosphere.

Line 21 contains the number of pounds of water of condensation drawn per hour from the reservoir between the middle and end cylinders, and measured in a tank. This tabular quantity is necessarily much less than the real quantity, owing to evaporation in the tank. The water when drawn from the reservoir had the temperature of the steam pressure in the reservoir; but, when in the tank, being exposed to only the atmospheric pressure and temperature, a considerable quantity must have escaped in vapor. Besides this, a large portion of the water of condensation from the middle cylinder and reservoir must have been swept onward by the steam current into the end cylinders.

Line 22 contains the number of pounds of coal consumed per hour. This coal is a prepared fuel of very superior quality, employed exclusively for the trials of the machinery of French naval vessels. It is formed of the fine coal from the Anzin mines in the northeast of France, carefully washed, dried, and then mixed with just enough coal-tar to give coherence when forcibly compressed into the form of bricks. The fine coal itself, before washing, is of the best quality found on the continent of Europe; after washing, it has less that 4 per centum of ash, and it makes no clinker. Its cohesion is sufficient to prevent it from falling between the grate-bars in small pieces, and its economic vaporization and rate of combustion are about equal to that of the best Welsh steam coal. For these experiments, the coal was weighed into sacks, each sack containing the same number of pounds, so that the weight of coal consumed during an experiment was ascertained by merely counting the emptied sacks.

Lines 23 and 24 contain, respectively, the number of pounds of coal consumed per hour per square foot of grate surface and of heating surface. These quantities are the quotients of the division of those on line 22 by the quantities on lines 4 and 5.

Lines 25 to 30, both inclusive, contain the pressures in pounds per square inch upon the steam-pistons as given by indicators attached to each end of each cylinder. A complete set of indicator diagrams was taken every half hour. On line 25 is the mean indicated pressure on the piston of the middle cylinder. The back pressure against that piston is not given in the original data of these experiments. On line 26 is the mean net pressure on the piston of the middle cylinder, obtained by subtracting 1·5 pounds per square inch from the mean indicated pressure upon it. On line 27 is the mean indicated pressure upon the pistons of the end cylinders; and line 28 contains the net pressure upon them, obtained by subtracting from the mean indicated pressure 1·5 pounds per square inch. Line 29 contains the mean back pressure against the pistons of the end cylinders; and line 30 contains the mean total pressure upon the pistons of the end cylinders, given by the addition of the quantities on lines 27 and 29.

Lines 31 to 38, both inclusive, contain the number of horse-power of 33,000 pounds raised one foot high per minute, developed by the engine. Lines 31 and 32 contain, respectively, the indicated and net horse-power developed by the middle cylinder alone, calculated from the area of the piston of that cylinder and the pressures on lines 25 and 26. Lines 33, 34 and 35 contain, respectively, the indicated, net and total horse-power developed by the end cylinders alone, calculated from the aggregate areas of their pistons and the pressures on lines 27, 29 and 30. Line 36 contains the aggregate indicated horse-power developed by all the cylinders, obtained by the addition of the quantities on lines 31 and 33. Line 37 contains the aggregate net horse-power developed by all the cylinders, obtained by the addition of the quantities on lines 32 and 34. Line 38 contains the total horse-power developed by all the cylinders, obtained by the addition of the quantities on lines 31 and 35.

Lines 39, 40 and 41 contain the number of pounds of coal consumed per hour per indicated, net and total horse-power developed by the engine. They are respectively the quotients of the division of the quantities on line 22 by those on lines 36, 37 and 38.

Lines 42, 43 and 44 contain the number of pounds of feed-water converted in steam consumed per hour per indicated, net and total horse-power developed by the engine. They are respectively the quotients of the division of the quantities on line 20 by those on lines 36, 37 and 38.

Line 45 contains the number of Fahrenheit units of heat consumed per hour for total horse-power developed by the engine. These quantities are obtained by multiplying, respectively, those on line 44 by the number of Fahrenheit units of heat put into the feed-water by the combustion of the coal consumed. That number of Fahrenheit units will be the total heat in Fahrenheit units above zero of the boiler-steam, minus the 50 Fahrenheit units in the feed-water when pumped into the boilers, and plus the Fahrenheit units in the superheating obtained by multiplying the quantities on line 15 by 0·4805. The quantities on line 45 express relatively the true weights of fuel employed in the formation of the steam in the boiler.

Lines 46 and 47 contain what would have been the number of pounds of feed-water vaporized per hour by the coal on line 22, had its temperature, instead of being 50 degrees Fahrenheit, been, respectively, 100 and 212 degrees Fahrenheit, and had it been vaporized under the standard atmospheric pressure of 29·92 inches of mercury instead of the pressures on line 6.

The quantities on lines 48 and 49 are the quotients of the division of those on lines 46 and 47, by those on line 22, and give the comparable vaporizations of the feed-water per pound of coal under standard conditions.

Line 50 contains, in per centum of the weight of steam (line 20) evaporated per hour, the difference between that weight and the weight present in the middle cylinder at the moment when the cut off valve closed, calculated from the pressure of the steam at the point of cutting off as given by the indicator diagrams. The quantities on line 50 show the per centum of the steam entering the middle cylinder condensed in it when its piston had completed the 0·88 of the stroke.

Line 51 contains the quantities on line 50 increased or diminished in the ratio of 60 to the number of double strokes made by the pistons per minute on line 12. The purpose of the quantities on line 51 is to show the effect on the cylinder condensations of the number of double strokes made per minute by the pistons.

[To be continued.]

EXPANSION OF STEAM IN THE STEAM-ENGINE.

By Chief Engineer ISHERWOOD, U. S. Navy.

TABLE CONTAINING THE DATA AND RESULTS OF THE EXPERIMENTS MADE AT THE MARINE ARSENAL IN CHERBOURG, DURING FEBRUARY, 1866, UNDER THE SUPERVISION OF DIRECTOR OF NAVAL CONSTRUCTION MOLL, BY SUB-ENGINEERS JOESSEL AND THIBAUDIER, OF THE FRENCH NAVY, ON THE COMPOUND ENGINE OF THE WAR STEAMER "CHER," TO ASCERTAIN THE RELATIVE ECONOMIC EFFICIENCIES OF SUPERHEATED STEAM USED WITH DIFFERENT MEASURES OF EXPANSION AND WITHOUT THROTTLING; USED WITH DIFFERENT BOILER PRESSURES, THE SAME MEASURE OF EXPANSION AND WITHOUT THROTTLING; AND USED WITH THROTTLING. ALSO, TO ASCERTAIN THE ECONOMIC EFFICIENCY OF SATURATED STEAM USED WITH SCARCELY ANY EXPANSION IN A SIMPLE TWO-CYLINDER ENGINE, FORMED BY OMITTING THE THIRD OR HIGH PRESSURE CYLINDER FROM THE COMPOUND ENGINE OF THE "CHER." LIKEWISE, TO ASCERTAIN THE ECONOMIC VAPORIZATION BY THE BOILER.

NUMBER OF LINE.			EXPERIMENTS MADE TO ASCERTAIN THE RELATIVE ECONOMIC EFFICIENCIES OF SUPERHEATED STEAM USED WITH DIFFERENT MEASURES OF EXPANSION AND WITHOUT THROTTLING.								EXPERIMENTS MADE TO ASCERTAIN THE RELATIVE ECONOMIC EFFICIENCIES OF SUPERHEATED STEAM OF DIFFERENT BOILER PRESSURES USED WITH THE SAME MEASURE OF EXPANSION AND WITHOUT THROTTLING.				EXPERIMENTS MADE TO ASCERTAIN THE INFLUENCE OF THROTTLING ON THE ECONOMIC EFFICIENCY OF SUPERHEATED STEAM.		Working as a simple engine with scarcely any expansion of the steam, which was saturated and admitted to only the two end cylinders by passing it through the middle cylinder whose exhaust ports were closed tightly, and the connecting rod disconnected.
			Maximum Boiler Pressure.				Medium Boiler Pressure.										
1		Designation of experiment,	A	B	C	D	E	F	C	H	I	J	K	L	M	N	O
2		Date of experiment,	February 8	February 5	February 6	February 7.	February 22.	February 21.	February 20.	February 23.	February 8	February 9	February 22.	February 23.	February 10.	February 16.	February 19.
3		Number of furnaces in use.	6	6	6·	6·	6·	6	4·	4	6·	6·	6·	4·	6·	6	6·
4		Square feet of grate surface in use,	87·514	87 514	87·514	87·514	87·514	87·514	58·342	58·342	87·514	87·514	87·514	58·342	87·514	87·514	87·514
5		Square feet of water-heating surface in use,	2249·525	2249·525	2249·525	2249·525	2249·526	2249·525	1499·684	1499·684	2249·525	2249·525	2249·525	1499·684	2249·525	2249·525	2249·525
6	ENGINE.	Steam pressure in boilers, in pounds per square inch above the atmosphere,	27·29	27·67	27·29	27 87	19·55	19·45	19·55	19·72	27·29	21·09	19·55	12·19	27·87	27·87	18·54
7		Steam pressure in steam-pipe near the cylinders, in pounds per square inch above the atmosphere,	26·22	26 71	26·36	26·96	18·62	18·47	18·38	19·06	26·22	20·03	18·62	11 61	26·90	26·90	17 80
8		Steam pressure in reservoir between middle and end cylinders, in pounds per square inch above the atmosphere.	19·35	14 13	12·19	10·45	15 09	10·45	9·48	8·71	19·35	16·26	15·09	11 76	14 71	12·77	15·00
9		Proportion of the throttle-valve open,	1·00	1·00	1·0	1·00	1·00	1·00	1·00	1·00	1·00	1·00	1 00	1·00	0·30	0·25	1 00
10		Fraction of the stroke of the piston of the middle cylinder completed when the steam was cut off.	0·88	0·60	0·50	0 40	0·88	0·60	0 50	0·40	0·88	0·88	0 88	0·88	0·88	0·88	0·78
11		Number of times the steam was expanded,	2·26	3·21	3·78	4·59	2·26	3·21	3·78	4·59	2 26	2·26	2·26	2·26	2·26	2·26	1·26
12		Number of double strokes of pistons made per minute,	66·34	61 37	58 14	54·57	58·78	53·70	51·10	48 11	66·34	61 25	58 78	51·25	59·68	53·68	66·27
13	TEMPERATURES	Temperature, in degrees Fahrenheit, of the steam in the steam-pipe near the cylinders, normal to its pressure as saturated steam, according to Regnault,	268·5	269 2	268 7	269·6	256·3	256·0	255·9	257·1	268·5	258·7	256·3	242 9	269·5	269 5	254 9
14		Temperature, in degrees Fahrenheit, of the steam in the steam-pipe near the cylinders, by observation,	280·0	285·4	279·5	287·6	278·4	276·8	278·6	278·6	280·0	280·4	278·4	273·2	289 4	285·8	267 4
15		Number of degrees Fahrenheit that the steam was superheated on entering the middle cylinder,	11·5	16·2	10·8	18·0	22 1	20·8	22·7	21·5	11·5	21·7	22·1	30·3	19·9	16·3	12 5
16		Temperature, in degrees Fahrenheit, of the steam in the reservoir normal to its pressure as saturated steam,	257·5	248·0	244·1	240·4	249·8	240·4	238 2	236·4	257·5	252·0	249·8	243·2	249·1	245·8	249·7
17		Temperature, in degrees Fahrenheit, of the steam in the reservoir, by observation,	257 5	248·0	244 1	240·4	249·8	240·4	238·2	236 4	257·5	252·0	249·8	243·2	249·1	245·8	249 7
18		Number of degrees Fahrenheit that the steam was superheated on entering the reservoir,	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0 0	0·0	0 0	0·0	0·0	0·0	0·0	0·0
19		Probable temperature of the feed-water, in degrees Fahrenheit,	50·0	50·0	50·0	50·0	50·0	50·0	50·0	50·0	50·0	50·0	50·0	50·0	50·0	50·0	50·0
20	WATER.	Number of pounds of feed-water pumped into the boilers per hour,	11574·885	8181·790	7033·121	6052·011	8477·225	5831·537	5208·186	4188·851	11574 885	9414·240	8477 225	5926·341	8201·633	6991·230	16548·778
21		Number of pounds of water of condensation drawn from the reservoir per hour,	37·717	35·276	30·866	35·276	17·638	15·433	15·433	15·433	37 481	26·457	17·638	8·819	22·047	13 890	2·205
22	RATE OF COMBUSTION	Number of pounds of coal (briquettes d'Anzin) consumed per hour,	1355 915	1009·771	881·896	787·092	1047·271	780·478	705 517	621·737	1355·915	1159·693	1047·271	734·178	1144 260	932·681	2017·337
23		Number of pounds of coal consumed per hour per square foot of grate surface,	15·494	11·538	10·077	8·994	11·967	8·918	12·093	10·657	15·494	13·251	11·967	12·584	13·075	10·655	23·052
24		Number of pounds of coal consumed per hour per square foot of heating surface,	0·603	0 449	0·392	0·350	0·465	0·847	0·470	0·414	0·603	0·515	0·465	0·489	0·509	0 415	0·897
25	STEAM PRESSURES IN CYLINDERS, PER INDICATOR.	Mean indicated pressure on the piston of the middle cylinder, in pounds per square inch,	18·926	19·197	18·578	18·739	14 872	16·250	15·366	14·034	18·926	15·803	14 872	11·091	15·215	13·870	....
26		Mean net pressure on the piston of the middle cylinder, in pounds per square inch,	17·426	17·697	17·078	17·239	13·372	14·730	13·866	12·534	17·426	14·303	13·372	9·591	13·715	12·370	....
27		Mean indicated pressure on the pistons of the end cylinders, in pounds per square inch,	16·080	11·186	9·606	7·660	12·337	8·182	7·354	6·508	16·080	13·277	12·337	9·537	12·018	10·208	25·545
28		Mean net pressure on the pistons of the end cylinders, in pounds per square inch,	14·580	9·686	8·106	6·160	10·837	6·682	5·854	5·008	14·580	11·777	10·837	8·037	10·518	8·708	24 045
29		Mean back pressure against the pistons of the end cylinders, in pounds per square inch,	1·273	1·070	1 474	1·678	1·354	1·451	1·432	1·892	1·273	1·312	1·354	1·480	1 379	1·217	3 452
30		Mean total pressure on the pistons of the end cylinders, in pounds per square inch,	17·353	12·256	11·080	9·338	13·691	9·633	8·786	8·400	17·353	14·589	13·691	11·017	13·397	11·425	28·997
31	HORSES-POWER.	Indicated horses-power developed by the middle cylinder,	182·312	171·069	156 839	148 484	126·934	126·553	114·015	98 100	182·312	140·548	126·934	82·547	131 850	108 111	....
32		Net horses-power developed by the middle cylinder,	167·863	157·702	144·176	136·599	114·132	114 857	102·885	87·617	167·863	127·208	114·132	71·383	118·852	96·419	....
33		Indicated horses-power developed by the end cylinders,	309·793	199·362	162·192	121·393	210·596	127·598	109·133	90·988	309·793	236·166	210·596	141·963	208 292	159·134	491·625
34		Net horses-power developed by the end cylinders,	280·895	172·628	136·865	97·621	184 761	104·206	86·873	70·053	280·895	209·484	184 761	119·635	182·294	135·750	462·756
35		Total horses-power developed by the end cylinders,	334·319	218·432	187 079	147·985	233·709	150·226	130·384	117·435	334·319	259·503	233·709	163·993	232·192	178·106	558·060
36		Aggregate indicated horses-power developed by all the cylinders,	492·105	370·431	319·031	269·877	337·530	254·151	223·148	189·088	492·105	376·714	337·530	224·510	340·142	267 245	491·625
37		Aggregate net horses power developed by all the cylinders,	448·758	330·330	281·041	234·220	298·893	219·063	189·758	157·670	448·758	336·692	298·893	191·018	301·146	232·169	462·756
38		Aggregate total horses-power developed by all the cylinders,	516·631	389 401	343 918	296·469	360·643	277·824	244·399	215·535	516·631	400·051	360·643	246·540	364·042	286·217	558·060
39	ECONOMIC RESULTS.	Pounds of coal consumed per hour per indicated horse-power,	2·755	2·726	2 764	2·917	3·103	3·071	3·162	3·288	2·755	3·078	3·103	3 270	3·364	3·490	4·103
40		Pounds of coal consumed per hour per net horse-power,	3 021	3·057	3·138	3·360	3·460	3·563	3·718	3·943	3·021	3 445	3 460	3·843	3·800	4 017	4·359
41		Pounds of coal consumed per hour per total horse-power,	2·625	2·593	2·564	2·655	2·904	2·809	2·887	2·885	2·625	2·839	2·904	2·978	3·143	3·259	3·615
42		Pounds of feed-water consumed per hour per indicated horse-power,	23·521	22·088	22·045	22·425	25·115	22·945	23·317	23·739	23·521	24·900	25·115	26·397	24 112	26·100	33·661
43		Pounds of feed-water consumed per hour per net horse-power,	25·793	24·768	25·025	25·839	28 362	26·620	27·420	28·470	25·793	27·961	28 362	31·025	24·235	30·113	35·761
44		Pounds of feed-water consumed per hour per total horse-power,	22·406	21·011	20·450	20·414	23·506	20·990	21·290	20·826	22·406	23·532	23·506	24·038	22·529	24·426	29·654
45		Fahrenheit units of heat consumed per hour per total horse-power,	25942·115	24251·243	23548·367	23582·641	27107·802	24201·907	24553·772	24012·810	25942·115	27151·618	27107·802	28092·489	26096·497	28197·427	34032·558
46	VAPORIZATION.	Pounds of feed-water that would have been vaporized per hour, had it been supplied at the temperature of 100 degrees Fahrenheit, and vaporized under the standard atmospheric pressure of 29·92 inches of mercury	12302·377	8697·238	7475·160	6433·789	8980·867	6177·677	5511·788	4755·872	12302 877	9980·360	8980·867	6255·134	8719·776	7432·271	17523·676
47		Pounds of feed-water that would have been vaporized per hour, had it been supplied at the temperature of 212 degrees Fahrenheit, and vaporized under the standard atmospheric pressure of 29·92 inches of mercury	13739·797	9713·429	8348·563	7186·517	10030·198	6899·481	6155·783	5311·551	13739·797	11146·472	10030·198	6985·988	9738·600	8300·647	19571·153
48		Pounds of water vaporized from 100 degrees Fahrenheit by one pound of coal,	9·073	8·613	8·476	8·174	8 575	7·915	7·812	7·649	9·073	8 606	8·575	8·520	7·620	7·967	8·687
49		Pounds of water vaporized from 212 degrees Fahrenheit by one pound of coal,	10·133	9·618	9·467	9·129	9·577	8·840	8·725	8·543	10·133	9·612	9·577	9·515	8·511	8·898	9·701
50	CONDENSATION.	Difference, in per centum of the weight of steam evaporated per hour in the boilers, between that weight and the weight of steam per indicator in the middle cylinder at the moment when its cut-off valve closed,	8·980	15·990	21·290	27·210	9·697	18·703	24·025	31·425	8·980	9·725	9·697	11·691	....	....	....
51		The quantities on line 50 increased or diminished in the ratio of 60 to the number of double strokes made by the pistons per minute,	9·922	15·958	20·630	24·733	9·493	16·736	20·441	25·198	9·922	9·879	9·493	9·985	....	....	....

MEMOIRS ON THE LIQUEFACTION OF OXYGEN, THE LIQUEFACTION AND SOLIDIFICATION OF HYDROGEN, AND ON THE THEORIES OF THE CHANGES IN CONDITION OF BODIES.

By R. Pictet.

Translated for the Journal of the Franklin Institute, by P. Pistor, M. E.

[Continued from Vol. lxxv, page 329.]

II.—Description of the Apparatus.

In the preceding chapter we have established the apparent antagonism existing between vapors and permanent gases; an antagonism resting principally on the anomalies of the law of Mariotte and on the impossibility of liquefying these gases, notwithstanding fabulous pressures.

Theory has led us to recognize the necessity of modifying the condition of the permanent gases, in two manners: by submitting them to increasing pressures and by lowering their temperature as much as possible.

We will now describe the mechanical devices chosen to attain this double purpose:

Before adopting any plan, notwithstanding a well-defined purpose, all the requisite conditions must be considered, to ensure a continuous operation, to eliminate error and the unforseen, which too often thwarts our purpose, veiling the distinctness of the phenomena to be observed, introducing disturbing elements which prevent accuracy of observation.

To succeed in liquefying the permanent gases, we find that the mechanical appliances must fulfil five essential conditions. They are all based on known facts relating to the liquefaction of other vapors. They are:

1. To operate on a gas absolutely pure, with no trace of a foreign gas.

2. To be able to compress this gas methodically; to obtain considerable pressures; and to be able to measure these pressures accurately.

3. To have the lowest possible temperatures available; to be able to maintain them indefinitely, at the same time abstracting heat at these low temperatures.

4. To have a large condensing surface, maintained at these low temperatures.

5. To be able to make use of the expansion of the gases, from their great pressure to the atmospheric pressure; which expansion, when added to the preceding aids, induces liquefaction.

These five conditions are equally important. If the gas were impure, liquefaction might be due to the foreign gas. The laws of pressure, when applied to temperatures, are disturbed by the presence of a foreign gas, in the one under investigation. It is, therefore, absolutely necessary to operate on a chemically-pure gas. 800 atmospheres have seemed, to us, as a sufficiently high limit for a first series of experiments. We have used a metallic manometer, manufactured expressly for this purpose, by M. Bourdon, and graduated, with the greatest care, by means of hydraulic pressures measured by a balance. Without being absolutely correct, this apparatus is sufficiently accurate to record a pressure to within 1 or 2 atmospheres; which suffices.

The manner of producing low temperatures will be the subject of the following description: It is the most expensive and most delicate of the mechanical part. A large condensing surface is necessary for the compressed gases, as the majority of the experiments previously undertaken with this object have miscarried for want of proper precaution in this respect.

A given surface will only condense a certain quantity of vapor. If this surface is small, if the sides are bad conductors of heat, the phenomenon of condensation will be greatly retarded. On this account, we do not wish to use thick glass tubes, and will give a large surface to the metal tube destined to condense the gas. Finally, in case the pressure obtained, joined to the influence of the temperature, should not suffice to bring liquefaction to a static condition, it can be accomplished by the expansion of the gas.

Let us imagine the gas compressed to a pressure of 500 atmospheres, and kept at — 100°; under these conditions it would still be gaseous. If we expand it from the pressure of 500 atmospheres to the atmospheric pressure, this expansion will perform considerable work. This work will be given out at the expense of the temperature of the gas, but this reduction of the temperature might be such that the gas would lose every trace of heat, and that a part of it would pass through absolute zero; the point where the calorific vibration is naught. Evidently, in this case, the cohesion, "if it is a universal force," would produce the liquid, and perhaps the solid, condition of the body under investigation.

In order to base this deduction on more accurate figures, we would remark that one kilogramme of oxygen would generate, as work of expansion, 49·664 kilogrammetres; whereas the total heat represented by a kilogramme of oxygen, from — 100° to absolute zero, is only 37·9 calories (French), which, transformed into work, only gives 16·334 kilogrammetres.

This shows that a complete expansion would not be possible; but a gas has, as a distinctive characteristic, an unlimited expansion, on account of which characteristic, lost during the operation, a part of the gas will condense and pass over into the solid or liquid condition. If this change did not occur, a part of the gas would become an inert dust, and then cohesion would not be a general law of nature.

This is, therefore, an absolute and final criterion. The expansion of compressed gases will furnish an unimpeachable proof.

Those are the principal considerations which have guided us in the mechanical arrangement we have adopted to liquefy the permanent gases.

We will now briefly describe the apparatus themselves. They may be divided into three distinct parts:

1. A circulation of sulphurous acid, producing a first fall in temperature.

2. A circulation of carbonic acid or of protoxide of nitrogen, which induces a second fall of temperature.

3. The generation of oxygen in a closed vessel, placed in contact with the solidified carbonic acid, in a long, fine tube, completely immersed in this carbonic acid.

Plate 1 shows plan and elevation of the arrangement.

These apparatus were placed in a building belonging to the Society of Geneva, for the manufacture of philosophical instruments.

M. Th. Turrettini, the director of this society, kindly authorized me to make use of his rooms and his steam engine, to facilitate my researches and experiments.

I avail myself of this opportunity to acknowledge my deep obligations to him as well as to the society he represents. All the instruments used were manufactured in this establishment, and it is solely due to their perfection, that accurate results were obtained without any accident whatsoever.

Fig. 1 represents an elevation of the whole apparatus. It shows a longitudinal section of two large drums, *U* and *V*.

In the upper one, *U*, is a large copper tube, *R*, of 12 centimetres diameter and 1 m. 10 in. in length. This tube traverses the drum from end to end, slightly inclined. The difference in level between the two extremities is 12 centimetres.

The liquid sulphurous acid is introduced into this tube through pipe *Z*, which enters on the upper side of the lower end of this cylinder. When the sulphurous acid has accumulated in this recipient so that the level of the liquid reaches the orifice of the tube *Z*, the surface of this liquid is at a maximum as it extends over the greatest cross-section from end to end.

A cock *r*, of 20 millimetres diameter, is placed on the upper end of the large tube containing sulphurous acid. This cock is opposite the tube for the admission of the liquid, placed at the other end. A long tube, 25 m. m. in diameter, connects this cock *r* with the suction of the first pump *P*.

If this pump be driven by means of any transmission of power, it will produce a partial vacuum over the sulphurous acid contained in tube *R*. Volatilization of the sulphurous acid will be immediately induced, and the temperature of this liquid will rapidly fall. The more perfect the vacuum, the lower it will drop.

In physical laboratories, air-pumps are generally used to create a vacuum; these delicate instruments would not suit this class of experiments which demand a continuous operation extending over many hours, and the abstraction of an enormous quantity of heat. On the other hand, common pumps do not render very good performance, and will not readily give us a perfect vacuum. I have surmounted the difficulty by coupling two pumps, similar to those used by us in our ice machines, and arranging them so that the suction of the second pump *P′* (Fig. 2), corresponds to the compression of the first *P*.

Owing to this arrangement, the clearance of the first pump, the piston leakage, small mechanical imperfections inherent to large industrial apparatus are completely neutralized and the suction becomes as energetic as that of the best air pumps. A few figures will suffice to show the remarkable efficiency of this arrangement.

I have obtained a vacuum of ½ millimetre in a flask containing liquid sulphurous acid, with an excellent air pump, having cylinders of 750 cubic centimetres capacity. The weight of the flask and acid was 320 grammes. The flask was wrapped in rags and cotton waste to prevent radiation or conduction of heat.

After having pumped without intermission for more than three-quarters of an hour, there being four of us to take turns, the indicated temperature was only — 54° ; twenty minutes later it was only — 55°, and we were unable to lower it.

With the two pumps coupled as described, the temperature of tube *R*, as indicated by the same alcohol thermometer was — 30° after four minutes' operation; —45° after ten minutes, and finally descends gradually to — 73°, the lowest limit we could reach.

The alcohol thermometer fits a small copper sleeve, the mouth of which opens into the side of the large reservoir *R*. The other extremity is closed, and the whole tube immersed in the liquid sulphurous acid. A little absolute alcohol is poured into this sleeve so as to establish contact between the walls of the tube and the thermometer.

The pumps *P* and *P′* are of cast iron, constructed on Prof. Daniel Colladon's plan, as applied to air compressors. The piston is hollow and is furnished with a circulation of water, which enables the packing to resist for a long time the injurious effects of the elevation of temperature; which cannot be counteracted without this expedient. The packing is composed of two parts, separated by a metallic ring. This ring takes the place of a chamber and serves to prevent the entrance of air. It acts in this manner: the second pump *P′* compresses the sulphurous acid to 1 or 2 atmospheres in a condenser C. This condenser is of copper, and has the shape of a tubular boiler. A current of water traverses the tubes of this condenser, and takes up the heat developed by the change of condition.

As the pressure produced by the second pump, when compressing, exceeds the atmospheric pressure, it is only necessary to join the metallic rings in the piston packing of the two pumps *P* and *P′* by a pipe, to the connection of pump P', with the condenser C; there is then no danger of an entrance of air into the apparatus. Should such an accident occur, it would immediately paralyze the action of the pumps, as the pressure of the gases in the condenser C would be constantly increasing and would soon exceed the assumed limits.

This precaution, of a purely practical nature, is indispensable to insure a performance of any duration.

The volume of pump P being three litres per stroke, explains the rapidity with which the temperature descends in tube R, as soon as the operation begins.

The valves of pumps P and P' have been made with very particular care. They are of steel, and the carefully ground seats of the clacks are of brass. The springs on the suction valves are very weak, but just strong enough to close the valve. The speed of the pumps varies between 80 and 100 revolutions per minute.

The sulphurous acid which is evaporated in tube R, owing to the large surface of the liquid exposed, passes through cock r into the first pump, thence into the second, and finally into the condenser. There the vapors condense, resume their liquid state and find their way to the lower part of the condenser. Here I have placed the opening for tube Z, which connects the condenser with tube R. A regulating screw valve q, enables us to give the necessary section of opening, so that the weight of liquid which flows out under the difference of pressure between the condenser and the tube R, may be exactly equal to that of the vapors exhausted during the same time.

As this weight is extremely small, representing but a few grammes a minute, it will suffice to barely open the valve q, giving the stem one-tenth of a turn at the most. In this manner the level of the liquid in tube R, will remain constant.

The cycle of the sulphurous acid is complete and the fall of temperature obtained in the large tube R will be permantly maintained by the mechanical work of the pumps P and P'.

This first circulation of sulphurous acid, is but an "expedient" to obtain carbonic acid or protoxide of nitrogen in a liquid state, in sufficient quantities. Should it be desirable to condense carbonic acid or protoxide of nitrogen by ordinary pumps, it would be necessary to subject these gases to pressures exceeding 30 to 40 atmospheres, even when using very cold water for the condensation.

These pressures cannot be obtained on a large scale; they can only be realized by means of special pumps, whose sale is very limited and which cannot stand continuous work.

If on the contrary, carbonic acid be compressed at a temperature of — 65°, the pressure falls to 4 or 6 atmospheres, a pressure very readily obtainable by means of pumps similar to P and P'. With this object I have placed in the centre of tube R a second tube, of a lesser diameter, having a length of 1·15 m. and 6 centimetres in diameter. This tube, marked S is consequently immersed in the sulphurous acid which totally envelops it, and it shares the low temperature of — 65°. Tube S acts as a condenser for the carbonic acid which is compressed in it by the action of two pumps O and O', resembling pumps P and P' in every respect and similarly arranged.

The carbonic acid is prepared with great care in two large glass jars filled with pieces of Carrara marble on which chlorhydric acid, added from time to time, is allowed to act. The disengaged gas is washed, then dried by a large apparatus full of chloride of calcium. It is then stored in an oil gasometer (G, Figs. 1 and 2), having a capacity of 1 cubic metre. A pipe, C, connects the gasometer with a three-way cock, K (Fig. 2).

On commencing the operation, this cock K is turned that the gasometer G is connected with the suction of pump O by means of pipes C and C'. The pumps O and O' are not started until the lower temperature has already been obtained in tube R by the action of pumps P and P'.

The condensation of the carbonic acid in tube S takes place immediately, under a pressure indicated by the manometer, m. It varies according to the quantity of gas admitted to the pumps O and O', but generally remains between 4 and 7 atmospheres. The temperature of the sulphurous acid always rises a little as soon as pumps O and O' have been set in motion.

This result is natural, as the carbonic acid which liquefies gives off all its latent heat to the sulphurous acid; the temperature consequently rises to — 50°. As soon as the condensation of the carbonic acid is retarded, this temperature re-descends immediately, oscillating constantly between — 50° and — 65°. All the gas contained in the gasometer will be drawn through the pumps, O and O', and will be compressed in tube S, where it liquefies readily. More than 2 kilogrammes may thus be obtained in a quarter of an hour. The carbonic acid once obtained, it is only necessary to use it for the condensation of the oxygen.

The special apparatus arranged for this purpose are placed in the long drum, *V*, which is just below the first one. This drum, similar to drum *V*, contains two copper tubes; their dimensions, however, are notably different.

A first and exterior tube is exactly 3·70 m. long, and 35 mm. in exterior diam. It is slightly inclined towards the ground, but in the opposite direction to tubes *R* and *S*. It is marked *D* in Figs. 1 and 2. This tube connects with the reservoir of liquid carbonic acid by the pipe, *t*. A regulating screw-valve, *p*, exactly similar to the regulating valve of the sulphurous acid, allows an opening or closing of the connection, as well as a regulating of the size of the orifice. I have placed the delivery of the liquid carbonic acid about the centre of the long tube, *D*, for a reason which I shall give later.

A second flange, *f* (Fig. 2), placed at the upper part of *D*, allows us to insert a pipe, *C″*, which leads from *f*, and establishes a connection between the top of tube *D* and the three-way cock, *K*. This arrangement given, let us see how the second circulation takes place. We commence by drawing off the gas from the gasometer, previously filled. As soon as all the gas has been liquefied in the condenser, *S*, the regulating valve, *p*, is opened; the carbonic acid enters tube *t*, and immediately lowers the temperature of tube *D*. The first drops which enter the long tube, *D*, meeting a metallic surface of the usual surrounding temperature, evaporate rapidly, and the vapors generated return to the condenser, *S*, to be re-condensed.

As soon as an equilibrium of pressure is re-established, a second quantity of the liquid descends into the tube, and produces a still greater lowering of the temperature of the sides of tube *D*. The carbonic acid thus gradually descends into the lower tube, *D*; accumulating, first, in its lowest part, the level gradually rises to the upper part, at flange *f*.

During this operation the manometer, *m*, which indicates the pressure in condenser *S*, informs us of what is occurring. Each time a certain quantity of liquid carbonic acid descends into tube *D*, still warm when compared with the very low temperature of the carbonic acid, a sudden rise of 2 or 3 atmospheres is visible on the manometer, *m*. This increase disappears rapidly, as it is caused by a reflux of the gaseous acid, which re-condenses and re-descends into tube *D*.

The manometer, m, having come to a standstill, indicating that the whole tube has acquired a temperature corresponding to that of the sulphurous acid in R, *i. e.*, about — 60° to — 65°, the three-way cock, K, is turned, so as to disconnect the gasometer and to connect the suction of pump O with the upper part of tube D, through pipes C and C''.

Great care should be exercised with this experiment, for should this cock be opened suddenly, the liquid contained in D would start into spontaneous ebullition, notwithstanding the low temperature, and a considerable quantity of this liquid would find its way into the piping and pumps. There the high temperature would develop such quantities of vapor that the surface of condenser S would be altogether insufficient to re-condense it. The pressure would reach 30 or 40 atmospheres in a few seconds, and an accident would certainly occur.

This connection should, therefore, be opened but gradually, so as to diminish the pressure of the carbonic acid slowly and uniformly. The regulating valve, p, should also be left open for a short while, so that we may be assured that all the liquid carbonic acid has descended into tube D. The difference in pressure caused by the action of the pumps will certainly accomplish it.

Close the regulating cock as soon as a thick hoar-frost whitens the piping $C''\ C$; this is a certain sign that the whole of tube D is full of liquid. At this moment a new and considerable reduction of temperature takes place. A vacuum is formed over the liquid carbonic acid, and the cold becomes so intense that this acid solidifies.

MEASUREMENT OF THE TEMPERATURES.

It is impossible to use alcohol thermometers to estimate temperatures so low. The contraction and dilation of this liquid no longer gives any reliable guarantee. For the measurement of these temperatures I have used the following formula, which I have derived directly from the mechanical theory of heat, applied to changes of condition :

$$l\left(\frac{P'}{P}\right) = \frac{[\lambda' + (c - k)(t' - t)]\ 431 \times 1{\cdot}293\ \delta \times 274\ (t' - t)}{10333\ [(274 + t')^2 - (274 + t')(t' - t)]}.$$

In this equation, $l\left(\frac{P'}{P}\right)$ is the Naperian logarithm of the quotient of the tensions at a point of saturation, at the temperatures t' and t.

t' is a fixed temperature, taken as a starting point; 0° or 100°, if possible, or an intermediate temperature given by a standard thermometer.

t is the temperature to be determined.

P is the tension recorded by the manometer when a vacuum is established, and corresponds to a temperature t.

P' is the tension of the vapor at a temperature t', and is given in M. Regnault's tables.

λ' is the latent heat of volatilization at the temperature t'.

c is the specific heat of the liquid, a mean between t' and t.

k is the specific heat of the vapor at a constant pressure.

δ is the density of the vapor compared with that of air; a density varying slightly with the pressure P, and which we can ascertain exactly by means of the law of co-volumes, given by M. Regnault.

If we give t successive values, and each smaller by 10 degrees than the preceding value, the curve of maximum tensions corresponding to the temperatures may be drawn: this curve furnishes a means for very exact and rapid observations of the temperatures.

This is not the place to derive this formula, nor the equations on which it is based. We would merely remark, that as applied to the vapors of water, of sulphurous acid, etc., it agrees to within a millimetre with the tables of M. Regnault, between the limits $t' = 200°$, and $t = 0°$, which limits correspond to the greatest differences, and have been determined with the greatest care.

We have just explained how the second circulation, of carbonic acid, or of protoxide of nitrogen is caused. Either gas may be used. This second circulation produces a fall of temperature, which reaches — 120°, and even — 140°, when the vacuum is a perfect one.

We will now take up oxygen and the appliances which enable us to utilize this intense cold, and to obtain a considerable pressure.

I have placed a second tube in the interior of tube D, smaller as regards diameter, but about 50 centimetres longer. This small tube is very thick, its interior diameter is exactly 4 mm., and its exterior diameter is 15 mm.; the length of this tube A (Figs. 1 and 2) is 4·16 m. This tube transverses the two heads of tube D, protrudes a few centimetres from the lower end, and about 50 cm. from the upper end. It is to serve as a reservoir for the compressed oxygen. A thread is cut on the lower part of this copper pipe, about 6 in. long; a steel sleeve, which has previously been tinned, is screwed on to it. On heating it a perfectly soldered joint is obtained. The steel sleeve is pierced in two places, at one a large metallic manometer, *m′* (Figs. 1 and 2), is attached, graduated up to 800 atmospheres.

The diameter of this manometer is sufficiently large to readily show the tenth of each division, corresponding to 10 atmospheres. The pressure can consequently be estimated to within one atmosphere.

The manometer connects with the central part of tube *A*, through a hole in the side of this tube, opposite the opening in the sleeve. The joint of the sleeve and manometer is made perfectly tight by means of a copper washer interposed between the two faced surfaces of the joint. This washer is slightly dished on both sides and makes so perfect a joint that no leakage need be feared.

The second orifice of the steel sleeve is for the passage of the liquid oxygen, and is placed below the manometer *m′*. It is very small, only 3 mm. in diameter. A small bushing, perforated by a hole of 1 mm. diameter, is screwed into this opening. Through its extremity the compressed gas and liquid will escape as soon as the steel screw *v*, which closes the extreme end of tube *A*, has been unscrewed.

The steel sleeve envelops the end of tube *A* completely. If a screw with a tapering point be screwed into the sleeve opposite the end of, and parallel to, the axis of the mouth of this tube, it will entirely close the opening of tube *A* as soon as the point is forced into the same. There is no danger of spreading the copper by a strong pressure as it is securely held by the sleeve. This arrangement gives the most satisfactory results.

The upper part of tube *A* is bent down towards the earth and connects with a large wrought iron flask *B* (Figs. 1 and 2). This flask was forged with the greatest care, so as to insure an exceptional quality and homogeneity of metal. In the interior is a cavity of exactly 1659 cubic centimetres capacity, The exterior dimensions are, 28 centimetres in length and 17 centimetres in diameter. The sides have an average thickness of 35 millimetres. A determination of its strength shows that such a flask can resist a pressure of more than 1500 atmospheres. The connection of tube *A* with flask *B* is made by means of a double joint similar to that at the manometer *m′*. A steel screw plug is screwed on to the end of tube *A*, and into the opening of the flask. A copper washer makes the joint and prevents any leakage of gas.

Before making the joint a known weight of chlorate of potassa, mixed with chloride of potassium, is introduced into the flask, which is then screwed on to the end of tube *A*. A crown jet of gas, similar to that used in the Perrot furnace, is employed.

Carefully regulating the flame, the temperature of the flask is gradually raised to the 485 to 500 degrees necessary for the perfect liberation of the oxygen. The mamometer *m′* enables us to follow the course of the operation. This arrangement allows us to dispense with the pumps for the compression of the gas; the chemical reaction being the sole source of the pressure.

The surface of tube *A* is relatively large, as 3 m. 62 c. of its length is imbedded in the solid carbonic acid.

Pipe *t* was connected with tube *D*, near the middle, so as not to run the risk of suddenly increasing the temperature of the liquefied oxygen, which will collect in the lower part of tube *A*.

The liquid carbonic acid does not enter tube *D* at its lowest temperature; a certain lapse of time is necessary to complete the reduction of temperature; during this time the condensed gas is necessarily under the influence of this calorific oscillation. The lower end, between pipe *t* and the manometer *m′*, however, solves the difficulty, as the crystallized carbonic acid therein maintains a constant minimum temperature.

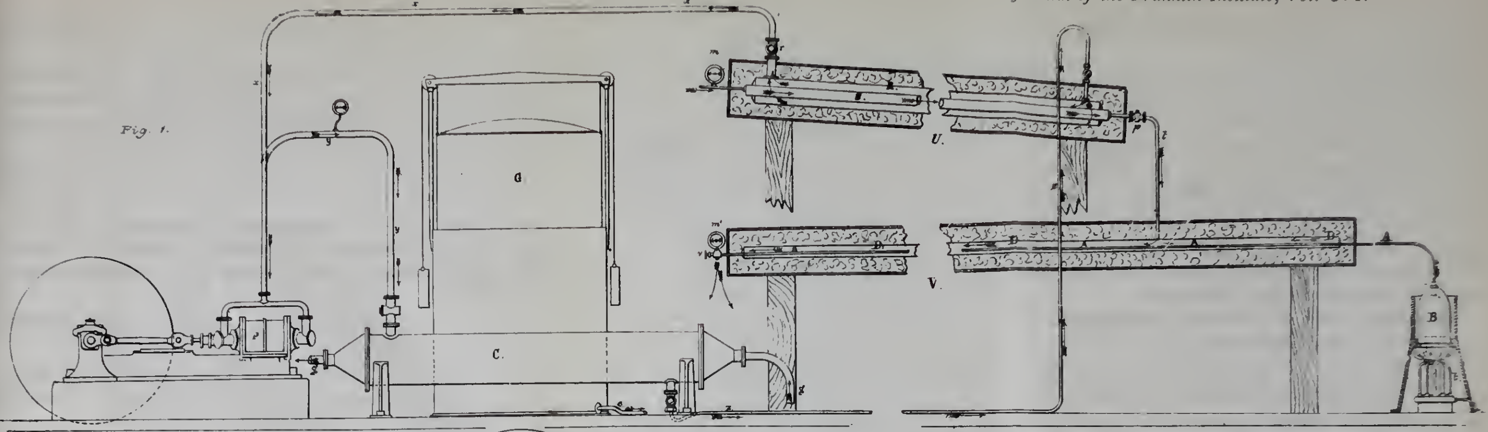
These are the general arrangements I have adopted to attempt the liquefaction of oxygen experimentally.

The preceding description having been necessarily long and interspersed with secondary details, I will recapitulate briefly, confining myself to the essential conditions, and will present them in an inverse order to that just followed.

Our object is to liquefy oxygen gas by means of low temperature and strong pressure.

In order to generate oxygen, we use a hollow iron flask, in which chlorate of potassa is placed, and which is gradually heated. The oxygen compresses itself in the enclosed space, by the energy of its liberation. We thus obtain great pressure. In order to subject the gas to low temperature, the upper part of the flask is connected with a long, thick copper tube. The same pressure will be found in it as in the flask, and a manometer affords a means of measuring the pressure with sufficient approximation for a first experiment. Around this tube, containing the oxygen under pressure, is placed a second

Fig. 1.



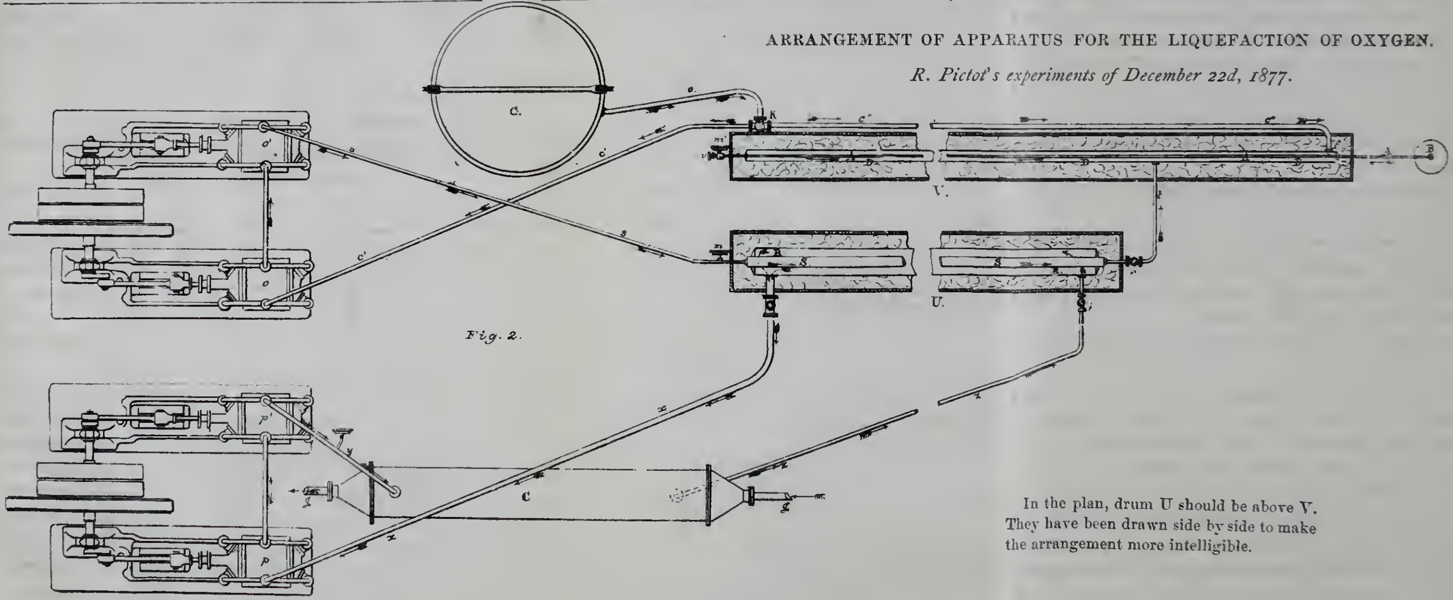


Fig. 2.

ARRANGEMENT OF APPARATUS FOR THE LIQUEFACTION OF OXYGEN.

R. Pictot's experiments of December 22d, 1877.

In the plan, drum U should be above V. They have been drawn side by side to make the arrangement more intelligible.

PHOTO-LITHOGRAPH BY J CARBUTT, 10 N NINTH ST. PHILA

tube almost as long, and which connects with a reservoir of liquid carbonic acid. Little by little, controlled by a conveniently placed regulating cock, liquid carbonic acid is allowed to pass into this long tube until it is filled. Two pumps then produce a vacuum over this carbonic acid, and lower the temperature until the liquid freezes and crystallizes.

The oxygen, subjected simultaneously to this low temperature and the enormous pressure produced by the chemical reaction, then condenses; which is proven, either by the character of the jet ejected from the orifice of the tube containing the oxygen or by the variations in the pressure recorded by the manometer.

In order to obtain a great quantity of liquid carbonic acid, we employ a mechanical expedient consisting in securing a first fall of temperature through the intervention of sulphurous acid.

The apparatus usually employed in the laboratory being far too inefficient, are replaced by this particular arrangement, which enables us to accomplish the liquefaction of carbonic acid or of protoxide of nitrogen on a large scale and with great facility.

These two circulations of sulphurous acid and of carbonic acid are "permanent," that is, the entire quantities of vapor exhausted by the four pumps, are transformed into liquid, and pass back into the tubes where they are again volatilized.

The mechanical work of the pumps represents exactly the "cold producing cause." A very close relationship exists between these two quantities; on the one hand we have the number of kilogrammetres developed by the steam motor, on the other hand the number of units of heat absorbed by the production of cold. The temperatures have a tendency to a permanent condition, corresponding to the greatest cold obtainable with the means described.

Let us imagine ourselves present inside of tube *A* (Figs. 1 and 2) during the liquefaction of 1 gramme of oxygen. The change from a gaseous to a liquid state liberates a great deal of heat. What becomes of this heat?

It first passes through the sides of the tube *A* and acts on the solid carbonic acid which surrounds this tube. A small portion of this body immediately passes over into a gaseous state. This change utilizes or absorbs all the heat furnished by the oxygen. The gaseous carbonic acid carries this heat over to the pumps *O* and *O′* and thence to the condenser *S*, there the carbonic acid resumes the liquid state and surrenders all the heat it abstracted from the oxygen.

The heat liberated by this second change of condition passes through the metallic sides of tube *S* and into the sulphurous acid in which this tube is immersed. Here, as before, a certain quantity of liquid sulphurous acid is evaporated, and acquires this heat by means of molecular motion. The vapors of sulphurous acid now pass over to the pumps *P* and *P′*, and are compressed in the condenser *C*. The last change of condition takes place, and the liquid sulphurous acid is reproduced.

The heat surrendered during this transformation passes through the metallic sides of the condenser *C* and into the current of water passing through the condenser. The water issuing from this apparatus, therefore, contains "all the heat surrendered by the oxygen," and this heat is drained off with this water of condensation. We have employed five successive changes of condition by this arrangement, to abstract the heat from the oxygen at a low temperature, and to transfer it mechanically to the drainage or waste water.

We think the above explanation will suffice to convey a sufficiently exact idea of the apparatus constructed, and will enable any one to easily follow the course of the experiments we will relate in the following chapter.

ON THE EROSIVE AND ABRADING POWER OF WATER UPON THE SIDES AND THE BOTTOM OF RIVERS AND CANALS.

By Clemens Herschel, Civil and Hydraulic Eng'r, of Boston.

[Continued from Vol. lxxv, page 403.]

Returning to a consideration of experiments made upon the power of currents to roll along materials, the year 1857 seems to have been the date of two sets of such. Mr. Thomas Login, M. Inst. C. E., in a short paper upon "The Floods of the Irrawaddy," printed in the "Proceedings of the Royal Soc. of Edinb., vol. 3, 1857, gives on page 475, the following table, reprinted in Stevenson's "Canal and River Engineering," 2d ed., page 315, as also in "Stevenson on

Harbors," page 165. These experiments were made in a small laboratory trough, in a stream "seldom exceeding half an inch in depth." If we are to judge from the fact that Mr. Login, in the many articles which he wrote on the "abrading and transporting power of water" in 1867–69, seems never to have once alluded to these experiments of his own, of ten or twelve years previous, we should conclude that he did not value them very highly; a conclusion that would be confirmed by a study of the arguments of these later articles.[1]

However, the following is the table:

MATERIALS.	Current required to move.	Rate of sinking in water.	
	FT. PER SEC.		
Brick-clay when mixed with water and allowed to settle for half an hour.	0·25	0·0095	Brick-clay in its natural state was not moved by a current of 2·1 ft. per second.
Fresh-water sand.	0·67	0·17	
Sea sand,	1·10	0·20	
Rounded pebbles, about size of peas.	2·00	1·00	
Vegetable soil.	0·90	(?)	

The other set of experiments made in 1857 are those by Thos. E. Blackwell, civil engineer, as Commissioner on Metropolitan Drainage, in the "accounts and papers" for 1857, ordered printed August 3d of that year. The table of results is on page 167 of the Appendix. It is reprinted in Beardmore's "Manual of Hydrology," on page 7, but omitting twenty-two sets of experiments. Though it might be inferred from the text that these experiments were made in a stream four feet wide by three feet deep, yet the drawing shows the experimental portion to have been only about eighteen inches deep. The channel was sixty feet long, and was made of rough but painted elm plank; the velocities were carefully and skilfully measured, and the record has been transmitted in exceedingly complete shape, so that these experiments rank very high among their particular kind. Fifty-three kinds of materials were experimented on, and the table is the record of four hundred and twelve experiments.

---

[1] Min. Proc. Inst. C. E., 1867–68, p. 471; *The Artizan*, 1869–30, and a series of articles later in the same volume: *Engineering*, 1869–1–412 and 1869–2–133; *The Engineer*, 1869–1.

TABLE SHOWING THE EFFECT OF RUNNING WATER IN MOVING VARIOUS SUBSTANCES.

DESCRIPTION OF OBJECT.	Weight in oz. avoir.	Cubic contents in ins.	Specific grav.	VELOCITY OF CURRENT.																
				0 to 1·00	1·00 to 1·25	1·25 to 1·50	1·50 to 1·75	1·75 to 2·00	2·00 to 2·25	2·25 to 2·50	2·50 to 2·75	2·75 to 3·00	3·00 to 3·25	3·25 to 3·50	3·50 to 3·75	3·75 to 4·00	4·00 to 4·25	4·25 to 4·50	4·50 to 4·75	4·75 to 5·00
Brickbat	22·0	18·5	2·05									start	0·94	1·15	1·25	1·30		2·14	2·31	
	16·0	13·6	2·03						start			1·15			1·50				2·31	
	9·0	7·33	2·12						start	0·7	0·82		1·20				1·87	2·00	2·61	
	6·0	4·76	2·18							start			0·42		1·2		2·00	2·14		
	3·0	2·59	2·00					start			1·00			1·50						
	16·0	12·98	2·13							start				1·11	1·50	1·58	2·00			2·73
Building Stone (Oolite)	22·0	17·68	2·15									start	1·00	1·15	1·25	1·43				
	9·0	6·70	2·32								start	0·91		1·15	1·20	1·25	1·87			
	3·0	2·39	2·17						start					1·36	1·43	1·87			2·22	
Chalk	22·0	18·54	2·05					start		0·60	0·67		1·20	1·30		1·67		1·76		
	16·0	12·74	2·17							start		1·00	1·11	1·50		1·87				
	9·0	7·78	2·00						start		0·93		1·36		1·87					
	6·0	5·18	2·00						start		0·92		1·15	1·58		1·67	2·14			
	3·0	2·39	2·17							start	0·75	0·94	1·03		1·77					
Flints	16·0	10·37	2·67										start		1·00	1·06		1·56	1·84	
	9·0	6·05	2·57						start	0·70				1·30	1·50					
	6·0	4·11	2·52							start		0·87					1·46	1·58		2·00
	3·0	1·95	2·66								start			1·07	1·36	1·43	1·76			
Coal	22·0	28·59	1·33				start				0·91			1·50	1·76	1·87				
	9·0	11·69	1·33			start	0·54			1·11			1·67			2·07				
	3·0	4·11	1·26			start	0·45			1·11			1·87	2·00						
Clinkers	16·0	11·67	2·37						start					1·36						
	9·0	6·05	2·57									start					1·15	1·50		
	3·0	2·39	2·17						start						1·50		1·87			
Copper Slag	6·0	3·46	3·00											start		1·07		1·67	1·76	
	3·0	1·73	3·00							start						1·21	1·76	2·00		
	1·5	0·86	3·00								start	0·79		1·11		1·76		2·00		

Limestone	5·0	3·02	2·86	....	....	....	....	....	....	start	....	....	....	0·94	1·11	....	1·58	1·67	....	....
	3·0	1·73	3·00	....	....	....	....	....	....	....	start	....	....	0·90	....	....	1·25	....	1·43	2·00
	1·5	0·86	3·00	....	....	....	....	....	....	....	start	....	....	....	....	1·00	....	1·25	....	....
Oyster shells	2·87	2·60	1·91	....	....	....	....	start	0·29	....	....	....	....	0·94	....	1·57	....	....	....	....
	1·12	0·86	2·24	....	....	....	....	....	....	start	....	....	....	0·38	0·86	1·12	....	....	....	....
	0·50	0·33	2·63	....	....	start	....	....	....	....	....	....	....	....	....	1·50	....	1·76	....	....
Slates	15·0	9·06	2·86	....	....	....	....	....	....	....	....	start	....	....	....	2·00	....	....	2·14	....
	9·0	5·4	2·88	....	....	....	....	....	....	....	....	....	start	....	....	....	....	....	1·00	1·58
	4·0	2·38	2·90	....	....	....	....	....	start	....	....	0·68	....	....	....	....	1·43	2·00	....	....
Nails	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	start	....
Scraps of Iron (small)	....	....	....	....	....	....	....	....	....	start	....	....	....	....	....	....	....	....	....	....
Ginger Beer Bottle	18·87	14·50	2·25	....	....	....	....	....	....	....	start	1·87	....	....	....	2·14	....	....	....	....
Glass Bottle (broken)	19·0	12·12	2·71	....	....	....	....	....	....	....	start	....	....	....	1·11	1·58	....	....	....	....
Brick on dab of Clay	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	start	about	6·00	....	....
Granite (broken)	6·50	4·22	2·66	....	....	....	....	....	start	....	0·65	1·00	....	1·15	1·25	....	1·76	....	....	....
	3·0	1·94	2·67	....	....	....	....	....	start	....	....	....	....	....	....	1·00	1·44	....	1·87	....
	1·50	0·97	2·66	....	....	....	....	....	....	....	....	start	....	1·11	....	1·30	1·50	2·00	....	....
Boulders	11·87	....	....	....	....	....	....	start	....	1·08	....	1·30	....	....	....	....	1·53	....	....	....
	5·87	....	....	....	....	....	....	....	....	start	1·11	....	....	1·67	....	....	2·14	....	....	....
	3·31	....	....	....	....	....	....	....	....	....	start	....	1·50	....	2·00	....	2·31	....	....	....
Sewage deposit	....	....	1·30	....	....	start	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Road Scrapings	....	....	1·78	start	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Gravel, ¼ inch	....	....	1·41	....	....	start	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" ½ inch	....	....	1·46	....	....	....	....	....	....	start	....	....	....	....	....	....	....	....	....	....
Sand (yellow)	....	....	1·81	start	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
" (green)	....	....	1·81	start	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

NOTE.—The figures in the table show the velocities, in feet per second, with which the various substances moved after they had started.

Says Mr. Blackwell: "These experiments allow the following inferences to be drawn: 1. For objects of the same character, the velocity required to start them, increased with the mass of the object. 2. For different objects the velocity increased with the specific gravity. 3. That according as the object assumed a form approaching a sphere, the less velocity it took to move it; whereas, a flat object, like slate, required a considerable current before it became disturbed from its position. And 4. As the velocity of the current is increased after an object is in motion, the velocity of such object increases in progressive ratio.

It is well to observe at once, that a velocity which will start an object will (when constantly maintained, and no accidental circumstances occur to prevent it,) never allow such object to deposit in the stream. Layers of the different objects were submitted to the action of the current, and the general results proved that the velocity required to remove them was considerably above that which would have been efficient in the case of a single object.

As a general conclusion, it may be observed that a velocity from 2 feet to 3·5 feet per second will remove all objects of the nature and dimensions of those that are likely to be found in sewers."

If the writer were to comment on these remarks, it would be to the effect that though the experiments do not, of course, disprove the very rational inferences above cited, and which would also result from careful *a priori* reasoning, they certainly show no regular laws of the kind indicated. It would be impossible to evolve from them, for example, a formula showing the relations between mass and velocity, or between specific gravity and velocity. In saying this, no fault is intended to be found with the experiments, but it is said for the purpose of pointing out the want of regularity in the action of currents of this kind and under such circumstances. The experiments were made to test whether, and they prove that "a velocity from 2 feet to 3·5 feet per second will remove all objects of the nature and dimensions of those that are likely to be found in sewers." Further than this, little can be concluded from them. [1]

---

[1] For the benefit of American readers, attention should be called to the fact that the oyster-shells spoken of in the table are puny little things, 2·5, 3, and 3·5 inches long. To move a "Stony Creek" or other prime oyster-shell, 9 or 10 inches long or more, would probably bother most sewer velocities.

An interesting point that seems to have been overlooked by experiments on artificial channels, or which they have as yet been unable to experiment on, is the effect of the inclination of the bed on which the materials to be rolled along are resting. In all the experiments made, this seems to have been very nearly horizontal, and such would be, approximately, the beds of all water-courses to which the experiments may be made to apply. But it is different with the *banks* of canals, and it is very conceivable that they would be easier affected by a simple straight current than the bottom of a canal or river, and that the current would cause certain portions of these banks to slide down to the bottom. We know, indeed, that waves have been observed to have an effect of this kind. In the Min. Proc. Inst. C. E., 1866–67, in the discussion on the use of steam power on canals, also quoted in Stevenson's "Canal and River Engineering," page 24, it is stated that on the Gloucester Canal, after the introduction of steam towage, the waves and other commotion in the canal (that were a result of the increased speed of the vessels passing through) caused the soft mud, which had formerly collected on the banks, to slide down these slopes, and kept them clean; in this case proving a benefit, for it had formerly been difficult to remove this mud with the dredge, for fear of injury to the banks; but the dredge could dig it up without such fear from the bottom of the canal.

There remain a number of data to be mentioned, having reference to the size and the behavior of materials as actually found in the beds of streams. On page 473, Min. Proc. Inst. C. E., 1867–68, Mr. Thomas Login says: "Experience on the Ganges Canal has shown that this (to have the deposits balanced by the abrasions) requires a mean velocity of about 3·75 feet per second, with a surface slope of a little less than fourteen inches in the mile." And on page 479, Mr. Login gives a "table showing approximately the sections and slope probably best adapted to irrigation canals and water-courses for Northern India." Coming as it does from a gentleman of long experience in this particular branch of the profession, it is entitled to serious consideration, to say the least. It is for each engineer to note the wide difference between the data given by Mr. Login and those derived from the trough experiments of Dubuat, and to decide to which he proposes to give the greater weight.

The following is the table above referred to:

TABLE

SHOWING APPROXIMATELY THE SECTIONS AND SLOPES PROBABLY BEST ADAPTED FOR IRRIGATION CANALS AND WATER COURSES FOR NORTHERN INDIA.

Cubic feet of discharge per second.	CALCULATED SECTIONS.					PROPOSED SECTIONS.			Side slopes of channels.	REMARKS.
	V, Mean velocity ft. per sec.	*H*, Hydraulic mean depth.	Breadth of channel at bottom.	Depth of water with full supply.	Slope of surface of water. Inches per mile.	Breadth in feet at bottom.	Depth in feet with full supply.	Slope of water surface, full supply.		
CU. FT.	FT.	FT.	FT.	FT.	IN.			IN.		
50	2	2	2½	4	15	2	4½	16½	1 to 1	Calculated on Beardmore's formula: $$\frac{11\sqrt{H \times S}}{12} = V,$$ where: H = Hydraulic depth in feet. S = Fall in ft. of surface of water per mile. V = Mean velocity in ft. per sec. In no case should the mean velocity exceed 4 ft. per sec, 3¾ probably being the safe limit, and not less than 2¾ ft. for the main channels. Keeping in mind that the greater the velocity, the cheaper the section in deep digging.
100	2¼	2½	4½	4¾	14½	4	5¼	16	1 to 1	
250	2½	3⅓	15	5	13½	13½	5½	14⅚	1 to 1	
500	2¾	4¼	27½	5½	13	25	6	14⅓	1 to 1	
1000	3	5	50	6	13	45	6⅔	14⅓	1 to 1	
2000	3¼	6	77½	7	13	70	7¾	14⅓	1½ to 1	
3000	3½	7	95	8	12¾	85	8⅘	14	1½ to 1	
4000	3½	7½	121½	8½	12¾	110	9⅓	14	1½ to 1	
5000	3⅔	7⅔	147½	8½	12½	130	9⅓	13¾	1½ to 1	
6000	3¾	8	170	8¾	12½	150	9⅔	13¾	1½ to 1	

On page 509 Mr. Login gives these additional data concerning the Ganges Canal.

No. of mile.	Point of observation.	Mean velocity. Ft. per sec.	Discharge. Cu. ft. per sec.	REMARKS.
1st.	Below the Regulator near Hurdwar.	5·10	6710	At the Regulator the water was 9 ft. deep. The bed was composed of pebbles, and had a slope of 2 ft. per mile, the water was quite clear.
19th.	Over the Solani Aqueduct at Roorkee.	4·48	6283	The depth of the water over the floor of the aqueduct was 8·25 ft. The water was slightly turbid.
50th.	At the head of the Futtigurh Branch above the Regulator.	3·46	5279	There was silt on the floor of the Regulator, and the water was very turbid.

And on page 544, Mr. J. T. Harrison, M. Inst. C. E., gives the following:

NAME OF RIVER OR CANAL.	Length of Canal in Miles.	Fall per Mile.	VELOCITY.		Discharge per day, in Gallons.	REMARKS.
			Ft. per sec.	Miles per hour.		
		IN.				
Ganges Canal to Nanoon..........	180	....	....	....	....	....
Cawnpore Branch	170	14	3·75	2·2	2.700,000,000	....
Etawah	180	... .	....	....	....	....
Ditto..........	....	17	....	3·0	....	Dangerous cutting bed.
	....	15	....	$2\frac{3}{4}$	....	Slightly "
	....	13·8	....	$2\frac{1}{4}$	....	Silting up.

On page 545, Mr. Login observed "that the slope of the Ganges Canal was originally projected at fifteen inches in a mile, and the calculated velocity of the current was four feet per second. In the year 1860, when he took charge of the works, the surface slope exceeded sixteen inches, with a mean velocity of 4·5 feet per second, and the bed was being eroded to a dangerous extent: this he had reduced to about fourteen inches in the mile, and the mean velocity of the stream had fallen to 3 75 feet per second. With this reduced velocity the bed began to silt up, and it had continued so for the last five years; therefore, he believed the proper slope and velocity had been obtained."

On page 541, Mr. Harrison states: "The Thames in some parts afforded an excellent illustration of the importance of maintaining sufficient inclination and velocity to enable the river to carry off mud. He had found that for several miles above Oxford the natural fall of the Thames valley was about fourteen inches in the mile, the minimum inclination at which, apparently, in this country as in India, large rivers could carry off mud. The river Thames formed a winding channel through this valley of deposited mud; by the introduction of locks, the inclination was reduced from fourteen inches to eleven inches per mile, consequently a considerable part of the Thames above Oxford was silted up, so that a boat drawing eighteen inches of water could not pass up the river."

In the article by M. Fargue, in the *Annales des Ponts et Chaussées*, 1868, already mentioned, it is stated that the mean width of the

Garonne, near Langon, is about five hundred and ninety feet. At low water the slope is about sixteen inches in the mile, though as much as eighty-nine inches to the mile in some places. The depth averages about ten or eleven feet. On an average of twenty-six years there were:

66·5 days of low water in each year,
195·0 days of mean water,
81·0 days of "bank full,"
20·8 days of ordinary freshet,
1·7 days of extraordinary freshet.

During these twenty-six years the average discharge was about 25,000 cubic feet per second (about 687 cubic metres), whence, as a grand mean for twenty six years and for all depths, the velocity would average about four feet per second.

The stretch of river under examination was about fourteen miles long, and the bed of this portion of it consisted of pebbles from 2·0 to 3·4 inches in diameter, mixed with thirty-three to fifty per cent. of sand. It had been in a virtually constant condition for twenty odd years.

RESULTS UPON THE RHINE.

Miles below Basel.	Pieces of gravel to the foot: $= l^3$ pieces, in one cubic foot.	Weight of largest piece. Lbs.	Velocity: Feet per second, at high water.	Slope in inches per mile.
2·5	8·4	13·5	12·	63·
20·0	10 7	10·5		
34·5	11·5	6 4		
58·5	?	4·9	10·	39·
90·0	12·4	3·3	8·	25·
115·0	16·9	2·2	Aver. 5·	Aver. 9·
165·0	18·1	0·2		

Professor Henry Sternberg, Director of the Polytechnic School of Carlsruhe, and a practicing engineer for fifteen or twenty years until he became professor in 1862, in an article in the Berlin *Zeitschrift für Bauwesen* for 1875, page 495, on the "Profiles and cross-sections of rivers bearing gravel," gives the foregoing table (the original in metric measures) of data concerning the Rhine, from Basel to Mannheim. Some data of slope and velocities are added, taken from a historical account of the improvement of this portion of the Rhine, published by the Engineering Department of the Grand Duchy of Baden. The Rhine flows on this length of one hundred and sixty-five miles, mainly between artificial banks, from two hundred and forty to three hundred metres, seven hundred and ninety to nine hundred and eighty feet apart; its maximum depth is about twenty-nine or thirty feet: average depth about sixteen or seventeen feet.

Finally, J. Schlichting, an engineer of the Prussian government, in charge of works upon the Memel, in the same journal for 1877, page 86, in mentioning Prof. Sternberg's article, says: "The mean velocity at the bottom of the Memel, as derived from the current measurements taken in five cross-sections, varied from 1 foot to 1·6 feet per second. On this part of the river the bed consists of fine sand, 'pin gravel,' and pebbles of the size of a pea, all mixed up; occasionally, larger pebbles are found, the size of a bean, say. This sand, pin gravel, and pebbles remain in constant motion, even at low water stages of the river, as may be inferred from the continual changes in the channel and the shoaling up of portions of it. This last operation is often completed in a few days, whence it may be inferred that the velocity of motion of these materials is quite appreciable." If it may be permitted to point out the somewhat curious course of reasoning in these sentences, the writer would call attention to the circumstance that the facts stated prove the deposit or cessation of motion of the materials on the bottom of the river, quite as much as they do that of their continuous movement. In other words, a bottom velocity of 1 to 1·6 feet per second, corresponds to a general movement of sand, pin gravel and pea pebbles, but it also corresponds to a deposit of the same class of materials. Or are we to infer that shoaling and scouring are in equilibrium at these velocities?

This case very well illustrates the difficulty of expressing a complex relation of this sort in figures. As an additional illustration, it may be instructive to consider the following table, compiled from data that have been given in this paper.

Diameter of pebble in inches or as described.	AUTHORITY. Funk. Large rivers.		Dubuat. Trough expts.	Umpfenbach Small brooks		Login. ½ in. depths.	Blackwell. 48 × 18 inches of channel.	Sternberg. River Rhine.	
	Surface veloc. observed.	Bottom veloc. calculated.	Bottom veloc. rudely measured.	Surface veloc. observed.	Bottom veloc. calculated.	Bottom veloc. measured.	Bottom veloc. measured.	Surface veloc. observed.	Bottom veloc. calculated
	PEBBLES MOVE WHEN VELOCITY IS IN FEET PER SECOND.								
Pea size	....	....	0·67	....	....	2·0	....	....	....
0·25	....	....	....	....	....	....	1·25 to 1·50	....	......
0·5	....	....	....	....	....	....	2·25 to 2·50	....	....
0·67	....	....	....	....	....	....	....	(5·0)	3·0
1·00	....	....	2·00	(3·1)	2·5	....	....	....	....
1·5	....	....	3·00	....	....	....	....	(10·0)	6·2
2·0	(5·6)	3·1	....	(5·2)	4·0	....	....	....	......

The conclusions of the writer may be summed up in the following paragraphs:

I.—Water, when in motion, acts or tends to act upon its channel in two ways. 1. By direct friction, tending to drag materials along its bed, or down its banks, if these have a sufficiently steep side slope; and 2. By lifting up materials, holding them in suspension, and thus carrying them along in the body of the current.

1. It is difficult to determine at what velocities any one kind of material will commence to move by direct friction of the water. It must depend on the specific gravity of the material, on the shape of its individual parts, on the nature and inclination of the bed it is to roll on, and to measure this velocity with any accuracy, the moving water must be free from all whirlpools or other relative motion of its particles among themselves, tending to lift up and carry off the material with which the experiments are being conducted. The effect of the simple friction of a stream of water upon its bed and banks is not a source of danger; its action is very slow, and it has never been shown to be of a dangerous character in any instance. It is apt, however, to produce shoals, similar to submerged, moving dunes (as in the Wisconsin River, above referred to), and thus to obstruct navigation, in the case of clear water rivers, flowing in a sandy bed, and in time of low water.

2. The exact force and other determination of the inner movements of the particles of water among themselves which abrade and erode banks and beds, lift up and transport materials, defies calculation or expression by formulæ in the present, or any at present conceivable state of hydraulic science. The effect of these inner movements must remain a matter of judgment in every especial case.

II.—For either kind of motion, and for every amount of it, there is a limiting size of individual objects of a certain specific gravity which will no longer be affected by such motion; therefore, just so soon as the beds and banks of a water-course are covered with bodies of this size and quality, those smaller and lighter having been washed away or covered up, the bed and banks must remain permanent.

Trouble, by reason of too much erosion, seems to have been confined, generally, to cases of undermining bridge piers and similar masonry or other structures placed in running water; the remedies for too much erosion have been either to diminish the velocity, and at the same time with it the relative motion of the particles of water among themselves, or the latter alone, by taking pains that the flow of the stream shall be as smooth, regular and uniform as possible; or else to protect the parts that suffer from erosion by stone pitching, fascines, and by similar well known kinds of covering.

Trouble, by reason of the shoaling up of channels, has been remedied by stopping the erosion, whence comes the material which was being deposited; this called for the same remedies, therefore, as the difficulty last considered. But when it was a case of the shoaling up of a canal, fed from a silt bearing river, or any similar case, in which the erosion of material could not be prevented, then reliance had to be placed upon an opposite course of treatment, and by an increase of absolute and of relative velocity, the scouring had to be increased until there was a balance between the tendencies to deposit and to deepen; or if it was the case of a river, shoaling from the effect of simple friction of the water on its bed, or a river in which considerations of high and low water volumes, and other such considerations, prevented the application of remedies proper enough in a canal, but inapplicable to the case in hand, the engineer may have arrived at a conclusion often reached before, namely: that the difficulty was one to be avoided rather than remedied. A scheme of "slack-water navigation," by means of fixed or movable dams, or a lateral canal, would then take the place of a river improvement. It would result from these considerations that canals are easier managed than rivers; and canals that carry clean water naturally are easier managed than those that come already loaded with silt into that part of their channel which is to be taken care of.

It has often been spoken of as a curious freak of nature that brooks and rivers running through low lands should still further diminish their fall per unit of length by forming curves and serpentines; but if it is true that curves and bends are the most potent cause of whirlpools, and other such commotions of the water that rivers are subject to, and that these commotions are the prime agencies in the abrading and transporting power of these rivers, then this matter has the appearance of a very beautiful feature in the economy of nature. For by no other known means could these rivers acquire this power of abrading and of transporting matter, and thus enabling themselves to maintain their channel and their very existence.

FUTURE WATER-SUPPLY OF PHILADELPHIA.

(Second Paper.)

By Henry P. M. Birkinbine.[1]

In my former paper on the future water-supply of Philadelphia, the various sources, with their present and prospective and comparative purity and their volume, were presented for your consideration; these were the Schuylkill River, Delaware River and the Perkiomen Creek.

In this paper it is proposed to compare the several means suggested for securing the future supply from the above named sources.

Schuylkill River.

1st. Increasing the water-power at Fairmount, by store-dams to keep up the flood-water and utilize it for power in times of drought.

In the former paper it was shown that the minimum flow of the Schuylkill past Fairmount was 200,000,000 gallons per day, that the mean daily flow when free from storm-water was 650,000,000 gallons per day, and that the maximum flow, or a mean of all the water flowing in the stream including storm-water, was an average of 1,665,000,000 gallons per day; but 1,000,000,000 per day of this is not utilized, it is wasted over the dam during freshets.

---

[1] Read before the Franklin Institute, May 15th, 1878.

What is proposed to be done is to construct store-reservoirs in the drainage area of the river to retain the storm-water and use it to make up deficiencies of low water.

In the report of the special committee of the Commissioners of Fairmount Park, on the preservation of the purity of the water-supply, 1867, page 13, the annual average of the three years (1863-64 65) is given as equal to a daily flow to waste (after supplying the city) of 4,242,416,396 gallons; and that this waste power would pump an average of 303,000,000 gallons per day. The amount of water which the special committee assert as flowing to waste, or over the dam without being employed in pumping, would require an annual precipitation many times greater than any of which we have record, indeed, nothing but such an amount of rain as falls in some tropical regions would produce so great a flow of water in the Schuylkill. The acceptance of this statement, without examination (no doubt by reason of the authority under which it is given to the public) has led to some of the schemes which have been brought out for supplying large additional quantities of water by the Fairmount water power.

Statements like the above require no further attention; and we will, therefore, assume the quantities given in my former paper to be correct, namely:

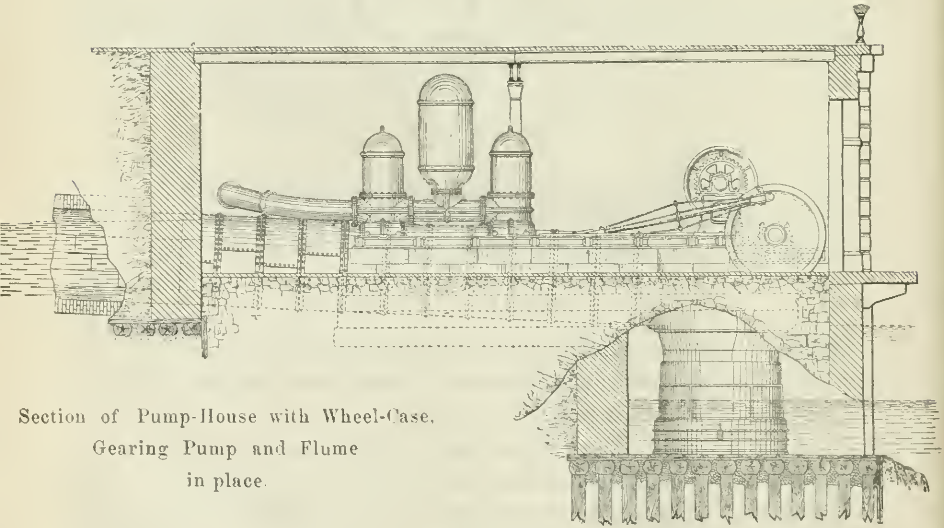
Minimum daily average, 200,000,000 gallons,
Mean daily average, 650,000,000 gallons,
Maximum daily average, 1,665,000,000 gallons.

The total average quantity of water passing Fairmount is represented by the last quantity which I have termed the maximum, and this will, therefore, indicate the utmost that can be secured from the Schuylkill by any system of store dams. Practically, it is impossible to utilize all of this water; some will be lost by leakage and by evaporation from the surface of the impounding reservoirs, and, unless their capacities are greatly in excess of the ordinary requirements, some will be wasted by extreme freshets, so that the total quantity of water which could practically be utilized at Fairmount, would not exceed 1,250,000,000 gallons per day. Estimating that it requires 15 gallons (the quantity generally assumed) to raise one gallon into the city reservoir. This would represent an average of 83,333,333 gallons per day, as the maximum supply of water procurable by water-power with the aid of adequate store dams, not 303,000,000 gallons, as represented by the report of the Park Commissioners.

PUMPING APPARATUS AT FAIRMOUNT.

There is but one of the original pumps and wheels remaining in the Fairmount works. This consists of a low breast (under shot) wheel propelling a double-acting piston pump. The pump is operated by a crank wheel on the main shaft of the water wheel. The wheel is 15 feet in diameter and 15 feet face; the pump is 16 inches in diameter, with 4 feet 6 inches stroke of piston. This is a simple and desirable arrangement, and is as efficient as any of the more recent motors and pumps. This wheel is stopped during high tide, and cannot utilize all the fall, a portion of it being lost at low tide; notwithstanding this, the old breast wheels pumped more with the same expenditure of power than the turbines and pumps now in the works, as will be shown.

FIG. 1.

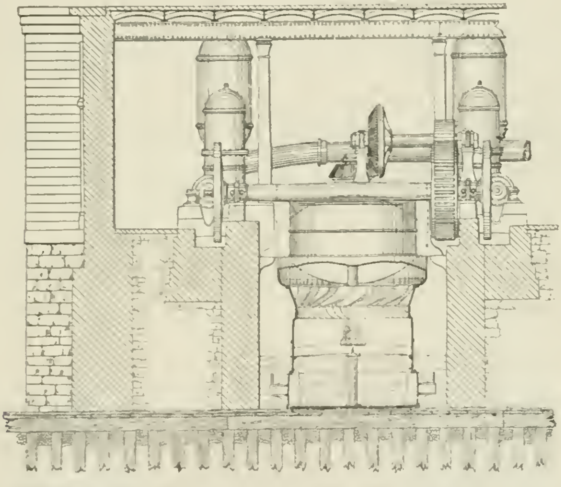


Section of Pump-House with Wheel-Case, Gearing Pump and Flume in place.

The reasons which led to the adoption of turbine wheels were: they could be better protected from ice; they could be run during the entire time, and, when the tide was out, the total fall of the water could be in part utilized. How to secure all these advantages, and the kind of motor to be employed, required careful investigation, and a series of experiments was instituted with various forms of turbine wheels.

A simple testing apparatus was erected at Fairmount works; it was not what would be termed a strictly accurate apparatus, but it was so arranged that the different wheel builders, with but ordinary knowledge of figures, could make their own measurements and calculations. Notwithstanding the imperfections of this apparatus, the tests were more reliable and better presented the peculiarities of the different wheels than those instituted at the Centennial Exhibition, in 1876, with such a display of pretended accuracy.

Fig. 2.



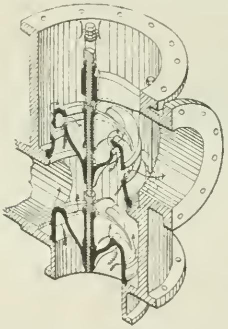
Transverse Section of Pump-House, with Turbine, Gearing and Pumps. The lower part of Wheel Case shown in Section, exhibiting Guide-Cams, Wheel and Gate

The plain Jonval Turbine was adopted, not only because of the high coefficient it gave, but it appeared better calculated to meet all the requirements of that particular location.

The head and fall at Fairmount varies from 8 to 14 feet, with the rise and fall of the tide below the dam.

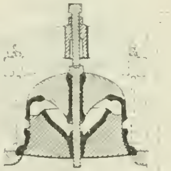
The turbine wheels and pumps, Figs. 1 and 2, put in the works in 1860, were under my own supervision, but are not now satisfactory to me. These wheels are 9 feet in diameter, with an area of issue equal to 1700 square inches, and will develop, when the tide is in and the fall is 8 feet, 108 horse power; when the tide is out, and the fall 14 feet, 250 horse power; at mean tide, 174 horse power. These wheels, of which there are three, each operate two double acting piston pumps, 18 inches diameter of cylinders, and 6 feet stroke of piston. They were constructed to pump into Corinthian Avenue Reservoir, 115 feet high. The work to be done is constant, while the power of the wheel varies with the rise and fall of the tide. The only direct means of utilizing this varying power was that of the difference in the velocity of the wheel due to the changing head; but this would not absorb the entire power. The pumps were so proportioned and geared as to absorb 105½ of the 108 horse power of the wheels when the tide is in; when the pumps made 23 strokes per minute. At mean tide, the pumps make 29 strokes and absorb 131 horse power of the 174 horse power which the wheels would give under that head. When the tide is out the pumps will make 35 strokes, and utilize 161 horse power, while the wheels will produce 250 horse power. It required pumps of peculiar construction to allow of the high piston speed necessary. This was accomplished by making the water-ways and valves of ample size, greater than the area of the pump cylinder. The valves, Figs. 3 and 4, are double-beat Cornish, made with a dash pot or water cushion, so as to prevent the faces coming in violent contact when closing. These valves, when in order, will close noiselessly, even when the pump pistons move at the rate of 250 feet per minute.

Fig. 3.



Isometrical Section of Valve-House, showing valve in place.

Fig. 4.



Double-beat Cornish Valve, with Birkinbine Patent Water-Cushion.

With this arrangement there was an average loss of 43 horse power at mean tide, and when the tide is out, of 89 horse power, or rather so much of the power of the wheels cannot be utilized, and is, therefore, to a great extent wasted. The amount of power actually utilized, as exhibited by the water pumped per hour into the reservoirs during 1876, was but an average of 105·3 horse power. The gates for controlling the wheels are simply cylinders placed below them on the draft tubes, and are raised to allow the escape of the water; the distance moved is the only means of controlling the quantity of water issued by them. The excess of power in the wheels above that which can be exerted upon the pumps is expended upon the friction produced by the gates retarding the flow of the water issuing from the wheels.

The arrangement of the machinery of 1870, is simply a repetition of the defects of the apparatus of 1860, with this difference, that the pumps are run to full working speed when the tide is in, and on account of defective arrangements of parts, the piston speed cannot be increased. The loss of power in these pumps is, therefore, much greater. Other forms of wheels might have been employed, such as are now well known and are controllable, so that a part of the power could be employed without materially affecting their coefficient of useful effect, or some arrangement made by which the power wasted could be utilized.

The amount of power employed in raising water, as shown by the water pumped per hour into the reservoir in 1876, was but an average of 105 horse power, less than one-half of the power of the wheels being utilized. These wheels at 8 feet will produce 143 horse power; at 11 feet 231 horse power, and at 14 feet 330 horse power. So that notwithstanding the increased size of the apparatus (the wheel being 10 feet 6 inches in diameter, 2250 inches issue, and 22 inch pumps), the amount of water raised is no greater than that by the smaller turbine wheels and pumps above described.

As long as the city depends for so much of its pumpage upon the water power at Fairmount, the utmost value should be obtained from it; and the subject has appeared so important that I have called the attention of the Water Department to these defects and the possible remedies.

The average amount of water furnished per day by Fairmount works in 1876 was 22,809,066 gallons. The maximum daily average for a month was, in May, 28,142,199 gallons.

With properly arranged and managed machinery, a daily average of 35,000,000 gallons could be pumped.

The wheels now in these works can absorb more than the average flow of the river. Little can, therefore, be gained by increasing the number of wheels. Having conceded the means of applying the power, we will consider

IMPOUNDING RESERVOIRS.

The special committee of the Park Commissioners suggested that a series of large store reservoirs be constructed to increase the water power at Fairmount, and presented estimates for doing the work, which made the plan appear feasible. But they estimate that a reservoir capable of containing 1,000,000,000 cubic feet (nearly 7,500,000,000 gallons) could be constructed for $200,000, a sum insufficient to purchase the necessary land which would be flooded, and pay for mill powers destroyed, if the available sites for such dams exist.

James F. Smith, C. E., Engineer of the Schuylkill Navigation Company, has presented a carefully thought out plan of storage reservoir. He proposes to raise some of the dams belonging to the Navigation Company, and to build others on the main stream, and also store reservoirs on the upper tributaries. No estimate is presented of the cost of this arrangement. Mr. Smith calculates that 4,595,243,931 gallons could be impounded by these dams and reservoirs. This, if utilized in pumping at Fairmount, would only raise 300,000,000 gallons into the city reservoirs, or taking 70 days of drought, it would add an average of about 4,000,000 gallons per day to the pumping power at Fairmount, an amount of water inconsiderable when compared with the demands of the city. This would require the purchase of eight dams, the raising of several more, and the construction of four new dams in the main stream and store reservoirs in the mountains. This plan represents about all that can be secured by impounding storm water for power.

There is probably no site in the drainage area of the Schuylkill where a large impounding reservoir could be as cheaply or as safely constructed as that on the Perkiomen, suggested for the gravitation works. The cost of this dam was estimated at $500,000. This reservoir could be utilized to store and furnish 5,000,000,000 gallons. This would furnish power to pump an average of, say, 4,500,000 per day during a drought of 70 days' duration.

2. *Purchasing the water power created by Flat Rock Dam.*—All the available power, except that required for the passage of canal boats, is now fully employed, and is leased by 13 different manufacturing establishments. This is equal to one thousand horse power, and produces an annual rental of $43,100, which capitalized at six per cent. would equal $718,333.33, but it would also be necessary to assume the cost of changing the power of the various establishments from water to steam, which would probably bring up the purchasing value to one million dollars. To this must be added the expense of utilizing this power for pumping water, wheel houses, wheels, raceways, pumps, pumping mains, etc., estimated by the Commission of Engineers, at $725,000. No more figures are necessary to show that this would make a much more expensive pumping arrangement than steam apparatus. When to these estimated expenses the annoyance of the co-occupation of the river with the Navigation Company, the delays and losses incident upon freshets and drought in the stream are taken into account, this, as a source of increased supply, loses all its supposed value.

3. *Raising Fairmount and Flat Rock Dams.*—Raising Fairmount Dam, say, two feet, could be done at a comparatively small cost; but the damages by overflowing and backing up the water would be great, notwithstanding the city is the riparian owner of most of the property affected.

The two feet additional would add 18 per cent. to the power of Fairmount pumps, but to utilize this would require machinery adapted to the increased head. The two feet added to the height would store 200,000,000 gallons; but this could not be utilized without impairing the power by drawing down the head. The additional supply by the increased head would be but from 4,000,000 to 5,000,000 gallons per day.

To raise Flat Rock Dam would require a new structure and large expenditures in head-gates and races. The value of property destroyed by the water—in land, factories and other buildings, in roads, railroads, etc.—would be very great.

If both of these powers were utilized for pumping water for the city—Fairmount Dam raised two feet, and Flat Rock Dam raised four feet—a daily average of 90,000,000 gallons might be pumped by water-power.

4. *Increasing the Capacity of the Works by Steam-Pumping Apparatus.*—In the report of the Water Department for 1876, p. 15, the cost of pumping an average of 50,000,000 gallons per day is given, one-half, by water-power, costing $18,000; the other half, by steam, costing $162,000; making a total of $180,000 per annum. From this data it is estimated that the cost of 100,000,000 galls. will amount to $504,000 per annum, one-fourth by water, three-fourths by steam. This would be at the rate of $720 per annum for each million gallons per day by water-power, and $6,480 per annum for each million gallons per day by steam; but this estimate only takes into account the direct expenses of running the works, viz., salaries, supplies and ordinary repairs. There are other expenses incident to furnishing the water, such as supervision, keeping buildings, grounds and reservoirs in order, renewals and extraordinary repairs. Taking these into account, the cost of furnishing the water supply to the city, in 1876, amounted to $298,718.71. Using these figures as a basis, the cost per annum of supplying 100,000,000 gallons per day, would be over $800,000. In this there is no estimate of the cost of the additional machinery which would be necessary to furnish the increased supply of an average of 50,000,000 gallons per day. It is not probable that this can be done, with economical and efficient machinery, so as to bring the annual cost of furnishing daily average of 100,000,000 gallons below $1,000,000 per annum.

The additions made within the past ten years, which have been from 20,000,000 to 25,000,000 gallons per day, have cost the city from $6,000,000 to $6,500,000, or, say, $250,000 per 1,000,000 gallons of increase per day. If the cost of the enlargement of the works be estimated upon this basis, an average increase of 50,000,000 gallons per day will cost $12,500,000.

The proposition which a responsible firm in this city made to Councils, for furnishing and operating a pumping-engine for five years, for the saving in the expense, as compared with Belmont Works, shows that there is great room for improvement in the pumping apparatus, and in cost of maintaining them.

DELAWARE RIVER.

The Commission of Engineers, in their report, present three plans for securing a supply from the Delaware River, by pumping.

1. *New Hope by Conduit.*—This plan proposes pumping a part by water-power, and will require the purchase of the power at that point. The distance to East Park Reservoir is 40 miles. The Commission estimate the cost of this plan (capitalizing the cost of steam-pumping) to be $23,000,000.

The supply is given at 75,000,000 gallons per day.

2 *New Hope by Canal and Conduit.*—In this project 31½ miles of the Delaware division of the Pennsylvania Canal would be purchased. The entire length of the canal, conduit, etc., to a reservoir at Lardner's Point, would be 43 miles. This, with the cost of pumping capitalized, is estimated at $22,500,000.

3. *Scudder's Falls by Conduit.*—This scheme would require the purchase of the Trenton water-power, the erection of a dam, the construction of 24 miles of canal, 7 miles of conduit to a reservoir at Lardner's Point, and steam-pumping machinery.

The distance would be 31 miles. The cost, with the expense of operating pumping engines, capitalized, would be $21,500,000.

DELAWARE BY GRAVITATION.

The supply of water from the Delaware by gravitation, is the most popular of all the modes and sources suggested, by reason of the great volume and comparative purity of the water, particularly when considered where it passes through the mountains at the Water Gap.

No surveys or estimates have been made for a works which would take the water from a point of sufficient elevation to deliver it into the reservoirs of the city by gravitation: we are, therefore, without data upon which to form an estimate.

At Easton, 83 miles from the city, the river is but 164 feet above tide, so that, to be satisfactory, it would require a conduit of at least 100 miles in length. The work would involve a very large expenditure of money, and presents many engineering difficulties in the peculiar features of the country which would confine the line of the conduit almost entirely to the vicinity of the river; the fact that the stream has cut its way transversely through the mountain ranges which cross the state: the tributary streams, and the valleys formed by them, which it would be necessary to cross, and the difficulties such as would present themselves in the vicinity of Easton, etc. So that, financially, the burden would be too great for a city of 1,000,000 of inhabitants, unless this were the only source from which a supply of water could be drawn.

PERKIOMEN CREEK.

The project of securing a supply of water from the Perkiomen, has never been in favor with the citizens generally, and notwithstanding it was presented to Councils in 1866, the Mayors, the City Councils, the Water Committee, the Chief Engineers of the Water Department and the Park Commission, have none of them been willing to assume the responsibility of recommending this source for a supply of water. The only public endorsement of the project is by the Commission of Engineers, in their report upon the future water-supply.

A large portion of their time was given to the investigation of the subject, and many pages of their report to a discussion of its merits. They also give plans and estimates for the construction of the work. Yet they have presented so many different suggestions, that, after all, we are not warranted in saying that they give it, or any other plan, a decided endorsement. They show it to be the best and most desirable source, and say of it, on p. 36 of their report: "In looking for a stream to furnish a gravity supply for Philadelphia, this tributary alone, of the many that flow into the Schuylkill, has been found to possess the proper requisites. Such a stream must possess a sufficient drainage area or water-shed; must not be too remote: must have a geological formation that will carry a good percentage of the rainfall to the reservoir: that will retain the water when impounded; and that will impart no mineral impurities. The region must be free now, and likely to remain free, from causes of pollution. A suitable site must exist for building a safe dam, and where a sufficient quantity of water can be impounded. *All these requirements are found to exist in the Perkiomen Valley.*"

With this exception, standing alone, so far as any public endorsement of this plan, let me ask your indulgence while endeavoring to present its claims somewhat at length.

The Perkiomen project is simply supplying the city from an artificial lake, fed by pure mountain streams. As presented to Councils, in 1866, it was as follows:

1. A lake or store-dam to be constructed where the trap-dike crosses the stream between Swenksville and Zieglersville.

The creek at this point has cut its way through the hills, which rise to from 400 to 500 feet above tide, and 200 to 300 feet above the bed of the stream. The trap-rock forms reliable foundation and abutment for the dam. This formation extends for a considerable distance across the country, and will form a complete barrier, preventing the water above it escaping. No better location could be desired than this for the constructing of a safe-dam of almost any desired depth and storage capacity. The one suggested in my report was to be 65 feet deep, and would cover 1500 acres with water, and would store 5,000,000,000 gallons, which could be used in time of drought, to make up deficiencies in the flow of the stream, or 100 days' supply for the present requirements of the city, if none was furnished by perennial springs or surface drainage.

2. A conduit to the city, to be constructed almost entirely of masonry, with a capacity of delivering 150,000,000 gallons per day.

Where pipes are used, as in case of inverted siphons, large saving in first cost could be effected by making them for a capacity of delivering 75,000,000 gallons per day, with the necessary arrangements for adding other pipes as the demands of the city made it necessary.

This conduit would be about 24 miles long, to a reservoir to be located in the upper part of the city. This reservoir to hold 1,000,000,000 gallons, to be constructed at some suitable site, with the water surface 170 to 185 feet above city datum, say, 75 feet higher than Fairmount Reservoir. Large feeding-mains to be led from the reservoir to various centres of distribution in the city.

The approximate estimates for the cost of the works were made without actually locating them, but were prepared after a survey and examination of the country between the Perkiomen and the city, and were liberal, so as to represent a sum that would be sufficient to meet all contingencies, and were as follows:

Lake or dam and land damages, . . .	$1,000,000
24 miles of aqueduct, at $250,000, . .	6,000,000
Store reservoir in the city, 1,000,000,000 gallons capacity, ...	1,000,000
Supply mains, to connect centres of distribution,	1,000,000
Contingencies, ...	1,000,000
	$10,000,000

The Commission of Engineers, in their report, give detailed estimates, with drawing, for a store-dam and conduit of much greater capacity. This was made by Wm. J. McAlpine, C. E., one of the Commission, an engineer of large experience in water-works construction. In this plan the lake or store-dam is to be made of such a depth as to cover 2,000 acres, and to allow the storage of 10,000,000,000 gallons; conduit, of a capacity for delivering 200,000,000 gallons per day; the estimated cost of the entire work is $10,860,730.

If the pipe-lines, and such parts as can be enlarged, are made with a capacity of but 75,000,000 gallons, and the permanent parts for 200,000,000, the works would cost, by this estimate, $6,782,172. Taking the present prices of labor and material, the works, as suggested by myself and presented to Councils, could be constructed for from $7,000,000 to $8,000,000.

This would enable the city to dispense with the small reservoirs, which, when considered as a part of the water-supply system of a great city, are of little consequence.

The pumping machinery of the various steam works, with much of the property occupied by them, could be sold. The value of these would make a large reduction in the actual cost of gravitation works.

The common objection urged to the Perkiomen, is that there is not enough water for the future demands of the city. The average amount of water supplied per day by all the works, in 1876, was 47,741,270 gallons. The daily average flow of the Perkiomen, as shown in my former paper, is, as per Commission of Engineers' Report, by Wm. J. McAlpine, C. E., 311,000,000 gallons. Calculated from data in Park Commissioners' Report, 250,000,000 gallons. My estimate, as presented to Councils in 1866, 240,000,000 gallons.

Taking the average of these, this stream will furnish more than five times the amount required for the present supply of the city.

The superior comparative purity of the source is also shown in the former paper. The Chief Engineer of the Water Department, in his last report, p. 14, says:

"Gravity and purity should be, and practically are, synonymous, and this mode becomes a necessity, if a pure, healthy water cannot otherwise be obtained." And again: "As all the conditions have been worked out and are known, as it applies to our own city, a comparison may clearly demonstrate why, as a matter of *purity*, *a gravity source is to be preferred;* while, as a matter of *economy*, *steam power* is our only plan, in the present financial condition of the city."

The facts presented in this paper demonstrate that in his conclusions the Chief Engineer has not considered all the elements of expense incident upon securing a prospective supply of water by steam-pumping; and it has been shown above, that, among the various plans suggested, there is none by which the future demands of the city can be met at less cost than by gravitation from the Perkiomen.

It needs no argument to demonstrate that the manner of enlarging the water-supply of a great city like this, as it has been done in the past fifteen years, by simply adding such facilities as the increasing demands make necessary from time to time—is not only a most expensive, but, when considered as a municipal improvement, most unsatisfactory.

The city has now 8 pumping-stations, 8 water-wheels, propelling 14 pumps, 16 steam-pumping engines, operating 25 pumps, 58 steam boilers, and 16 reservoirs at various heights.

If I have succeeded in showing that of all the plans suggested the Perkiomen gravitation project will secure an abundant supply of pure limpid water, at an increased elevation, and at a lower cost than any other of the schemes presented for a future water-supply of the city, and have thus made friends for a plan which seems to be a natural provision for our benefit, I shall feel that, in preparing and presenting these papers, I have done much to benefit the city we all love, and which deserves a purer and more copious water-supply than is now given to it.

The Lyons Globe.—There is said to be a terrestrial globe in the Jesuitic Library of the Lyons Lyceum, which is 170 years old, containing in great detail the curious system of African lakes and rivers, which the English and American travelers have lately re-discovered. It is two metres in diameter, and an inscription, near the north pole, states that it was made in the year 1701, by F. F. Bonaventure & Gregoire, Brothers of the Third Order of St. Francis. The globe has created a great sensation among geographical savans and amateurs, and it will probably be placed in the French Exposition.—*Les Mondes.* C.

ON THE EVIL EFFECTS ARISING FROM THE USE OF DOLOMITIC LIME IN BUILDING BRICK WALLS.

By Henry Pemberton.

In an able and recent paper by Mr. William Trautwine, published in the Journal of the Franklin Institute,[1] the author remarks that "the disfiguration of brick house fronts is now so general as to render it to the interest of brickmakers and builders particularly, that its causes may be determined and a remedy applied if possible." Mr. Trautwine shows that the ultimate cause thereof is the sulphur existing in the coal consumed in the processes of manufacture and of domestic life: the proximate causes, however, being twofold. First, the existence of silicate or other salts of magnesia in the brick-clay, converted into sulphate of magnesia in the process of burning in the kilns, by the sulphurous vapors from the coal. And, secondly, the employment of lime containing magnesia for the mortar used in the walls, which, by the absorption of the sulphurous vapors of the coal gases in the general atmosphere of the city, becomes converted into sulphate of magnesia, and being dissolved by the rain, penetrates the substance of the more or less porous bricks, efflorescing ultimately upon the surface.

Unsightly and disfiguring as this white efflorescence may be, it is, to the owner of the building, the index to a more serious evil, viz.: the disintegration of the mortar uniting the bricks, causing the destruction or fall of the chimneys and the washing-out of the joints, particularly in the back walls or gable ends of houses, where the bricks are irregular in size and the said joints are consequently thicker. The cavities and open joints thus produced facilitate the destruction, until the retained moisture penetrates the wall and compels the owner to refill or repoint the joints at a heavy cost—the whole proceeding probably to be repeated after a few years.

A careful consideration of all the facts connected with the above, shows that, although the salts of magnesia formed in the brick itself during the burning are sufficient to explain the first appearance of the white salts on its surface apart from any other cause, yet the amount thereof is too slight to account for the continued reappearance, inasmuch as the magnesia in the brick-clay seldom, if ever, exceeds the *one-half* of *one* per cent., and although this quantity, when converted into the soluble sulphate would be drawn by capillary attraction to, and accumulate upon, the surface of the bricks, yet, being washed off by successive rains, the supply from within would soon be exhausted, if not fed from some other source. Unfortunately, this source is abundantly found in the magnesian lime used in the mortar.

---

[1] Vol. CV, page 259.

A curious contradiction exists between the statements of nearly all European writers as to the influence of the presence of magnesia in lime used for mortar, and the practical experience of builders with regard thereto.

It is generally taught in most text-books that the presence of magnesia is very injurious: thus Liebig's "Handwörterbuch" says: "Ten per cent. even of carb. of magnesia in the limestone is injurious." Rudolph Wagner, in his "Chemischen Technologie," Bd. i., S. 397, says: "The effect of ten per cent. of magnesia in the lime can clearly be seen in causing it to become 'lean' (*mager*). Twenty-five and thirty per cent. renders it perfectly useless!" Dr. G. L. Hogeboom, in the article "Cement," in the "American Cyclopedia," says: "When the proportion of carbonate of magnesia is forty-six per cent., the stone is called Dolomite, and has been pronounced unfit for making building-mortar. It does not become so hot or set so soon as a pure lime, but those who use it assert that in time it becomes *harder*."

The analysis of mortar from various sources, both ancient and modern, given by Spiller, in Muspratt's "Chemie," 3d Auflage, Bd. 3, S. 1542, shows that in Vienna the mortar used contains lime and magnesia in the ratios of from five to one to two to one, yet the statement of R. Wagner, above given, is copied a page or two before. This discrepancy arises, probably, simply from the fact, that workmen accustomed to the use of any special kind of lime, reject as unmanageable any other lime that requires a different manipulation, either in the act of making mortar or in laying brick therewith; thus local habits or prejudice will accept one material at one place as being merchantable and the best, that at another place will be rejected as worthless, and *vice versa*.

To the existence of this common trait in mankind, Philadelphia is largely indebted for the trouble in question.

Having had, some years ago, frequent occasion to examine into the composition of the lime used here for building and other purposes, I found that no lime available for chemical purposes would be accepted or used by builders. The latter using, without exception, a strongly magnesian lime, seldom, if ever, containing less than thirty per cent. of magnesia in the calcined lime, whilst lime for chemical purposes (most from limestone), containing over ninety-eight per cent. of carbonate of lime, is readily obtainable in any quantity within a few miles of Philadelphia, and is sold here at a lower price for agricultural and chemical uses than the ordinary builder's lime.

The character and necessary chemical behavior of these magnesian limes can be clearly seen by the following analysis I have lately made of fair average samples taken from the lime used in the block of handsome dwellings now being erected on the square of ground between Twenty-second and Twenty-third Streets, and Spruce and Pine.

It contains in 100 parts,

Lime,	57·18
Magnesia,	37·38
Silica,	1·19
Iron and Alumina,	1·03
Sulph. Acid (a trace only), Manganese, Alkalies, Carbonic Acid and Water,	3·22
	100·00

Or only 3·08 per cent. more lime than would be required for equal equivalents, or a perfect Dolomite.

That a cement composed of a substance, nearly one-half of which is readily attacked, dissolved and formed into a soluble salt, crystallizing with seven equivalents of water; or, in other words, of which every 100 lbs. of lime used contain enough magnesia to form 230 lbs. of Epsom salts or crystallized sulphate of magnesia—that such a cement *must* be disintegrated, washed out and destroyed, if the sulphuric acid required be furnished, is self-evident. That it *is* furnished we have ocular demonstration. That the destruction is not more rapid is surprising. The quantity of sulphuric acid (or rather sulphurous, ultimately becoming sulphuric) furnished by the coal consumed in the city, is enormous. Some idea of it may be formed from the following observation: In preparing carbonic acid for chemical purposes on a large scale, it is usually obtained by the combustion of coal under steam-boilers and purification by washings, etc. To wash the gases resulting in twenty-four hours from the combustion, in said time, of 6000 lbs. of coal, yielding a gas containing from eight to ten per cent. of carbonic acid, a coke tower of eight feet in diameter by twenty feet in height was required, through which was passed, in fine spray, forty gallons of water per minute. This water, escaped from the tower at a temperature of about 110° Fahrenheit, consequently could retain but little carbonic acid, yet it permanently and powerfully reddened litmus paper, and was perceptibly acid to the taste. As this process ran continuously night and day, it showed that 6000 lbs. or three tons of coal rendered decidedly acid 480,000 lbs. of water. That most of the acid thus generated by the combustion of coal, is dissipated and lost in the atmosphere, is a matter of course, but enough must be caught by descending showers (or more effectively by mists and fogs) to cause apparently greater damage than we really sustain. No remedy can be applied to prevent or remove this production of acid. Our only recourse can be, therefore, to employ a lime free, or nearly free, from magnesia. Since the solubility of sulphate of lime is so slight (it requiring about four hundred times its weight of water, whilst sulphate of magnesia dissolves in twice its weight), it may be considered practically insoluble. Pure lime, as already stated, is abundant and cheap, but the prejudices of the workmen prevent its use. The behavior of a mortar made from magnesian lime is so different from that from pure lime as to render it easy to understand why the prejudice exists. Magnesian lime, in contradiction to most European authorities, forms, when slacked, a gelatinous, fatty mass, absorbing much water and permitting a large amount of sand to be mixed with it. The bricklayer, when using it, spreads out the mortar on the surface of the brickwork already laid as far as he can reach, without removing his feet from their position. He then places the brick in line upon this bed of mortar, placing as he does so, a little mortar on the end of each brick as laid, until perhaps seven or eight or more are in place, then points up the brick with the trowel on the face of the work. With *pure lime* mortar, this plan will not do. The mortar, when laid on the brickwork, becomes soon so firm—being less gelatinous or *pasty* than the magnesian—that two or three bricks only can be laid before it *sets* or becomes so dry as not to make a proper bond with the new brick and those already laid. Consequently, the bricklayer, accustomed to the magnesian lime, promptly and persistently rejects the pure lime as worthless, since he cannot execute the work expected of him in a given time, nor, probably, if used by him, would the bricks be securely and properly bedded.

That this is a local habit only, can be abundantly proved. In Pittsburgh, for instance, the only lime available is that from the limestone of the coal measures, containing only two or three per cent. of magnesia, or lime from the neighborhood of the "Sinking Valley," Tyrone, Hollidaysburgh, or other places near the eastern foot of the Alleghany Mountains. Throughout all this section, the lime produced and used is nearly free from magnesia, seldom if ever exceeding five or six per cent., and often less than one per cent. The bricklayers accustomed to it, know no other, and use it with entire satisfaction. No incrustation occurs there, notwithstanding the enormous consumption of coal in the city and immediate neighborhood.

The following experience may show still more clearly the influence of habit and accustomed ways upon those in the above trade. A few years ago, having occasion to erect large buildings in the suburbs of this city, in which more than a million bricks would be required, and having direct railroad communication with the west, by which lime produced in the neighborhood of Tyrone could be delivered from the quarries and kilns under my control, at first cost, cheaper than the ordinary lime used in the city could be carted, several car-loads were sent on. The lime being a nearly pure carbonate, with less than two per cent. of silica, iron and alumina, and about one per cent. of magnesia. Many millions of bricks had been laid with the identical lime in the west under my direction, in all sorts of constructions, from furnaces to dwelling-houses. On its arrival, in good condition, fresh from the kilns, it was slaked and mixed for mortar, but pronounced worthless and unfit for use by the workmen and master builder, notwithstanding the assurance given them that the same lime from the same quarries and kilns had been in constant use for years. On examination into the matter, it soon appeared that it would be cheaper to pay thirty per cent. more for such lime as the workmen wanted and were accustomed to, than to force the use of the other lime, at the risk perhaps of an *emeute* between the bricklayers and their employers. The stonemasons found the same fault, viz., it set too quickly and they could not make good work with it. Its use was therefore abandoned and other lime substituted.

If the workmen from Alleghany county had been removed to Philadelphia, and those from Philadelphia to the former county, each party would have been dissatisfied with the new material furnished them. Experience of twenty years having shown the excellent qualities of the western lime for those who know how to handle it.

I have thought it might be of interest to present this grouping of facts and experiences, so that those who might wish to use pure lime in Philadelphia, as the proper preventive of the destruction of their walls and buildings, might know where to look for the cause of the past and present universal use of a bad building-material and the difficulties to be anticipated in supplanting it by a better one.

THE MICROPHONE.

Extract from the Secretary's Report at the meeting of the Franklin Institute, June 19th, 1878.

The discoveries recently made in relation to the laws of electricity and its application to useful purposes, have attracted more popular, if not scientific, attention than at any time in the history of that science.

Prominent among these is the articulating telephone of Prof. A. Graham Bell, which seems to have opened up an entirely new field in electrical investigation. This instrument is too well known to you (having been presented at the meeting in September last)[1] to need any further reference here, except to say that with all the inventions since made in connection with the telephone, the receiving instrument still remains, essentially, as first presented by him.

---

[1] See Vol. CIV, page 219.

The next important discovery in this connection was by Mr. Thos. A. Edison, that carbon, properly prepared (in a finely divided state), possessed the property of changing its conductivity by pressure, and that the ratios of these changes correspond with the pressure brought to bear upon it.

This discovery is embodied in his carbon transmitter, presented here at the February meeting.[1]

Many modifications of, and some entirely new, transmitters were presented during the next few months, but no great step was taken until Prof. Hughes (also an American, although residing in England) discovered that when two or more electrical conductors rested lightly upon each other, the variations in the force of contact, caused by exceedingly feeble sonorous vibrations, would so vary the electrical resistance as to take up and transmit these vibrations, to the distant telephone, with great force and distinctness.

This discovery was first publicly presented in a paper read before the Royal Society, on May 9th last.

He started with the idea that variation in tensile strains would produce the same results as variations in pressure. As sonorous vibrations of a wire produced rapid variations of strains in its different parts, he placed a stretched wire in the circuit of a small battery and a Bell telephone. The wire was plucked, and the strains varied up to breaking, but no sound was observed until at the instant of rupture. He then sought to imitate the condition of the wire at the moment of breaking, by replacing the ruptured ends with a varying pressure, and found that if the ends simply rested upon each other, sounds made near them were distinctly reproduced. Further experiments soon showed that any two conductors placed in the circuit, in a similar manner, would produce the same result.

Thus two common nails, placed a short distance apart, and joined to the ends of the wire, and a third nail, or a piece of coin, laid across them, thus completing the circuit, would transmit delicate vibrations.

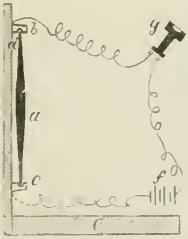
Prof. Hughes tried many substances, in a variety of forms, but that which seemed to answer best was willow-charcoal, treated by heating to a white heat, and plunged into mercury—thus filling its pores with that metal. Gas-carbon was nearly as good, even without metallizing, and has the great advantage of not oxidizing.

---

[1] See Vol. CV, page 266.

The most sensitive form of transmitter is that shown in the figure, which he has named the Microphone, from its ability to magnify sounds. This consists of a lozenge-shaped piece of gas-carbon, *a*, one inch long, one-quarter inch wide at its centre, and one-eighth inch in thickness. This is sustained in an upright position by two small blocks of similar carbon, *b c;* resting on its pointed end in a small cavity in the lower block, its upper end playing freely in a like cavity in the other block. These carbon blocks are attached to any convenient support; in this case, a thin piece of board, *d*, nailed roughly to a heavier piece, *e*, forming a base. The form of the upright carbon is of no importance, provided its weight is only sufficient to make a feeble contact.

The amount of battery power necessary to operate the microphone is very small, any form answering the purpose. Indeed, very satisfactory results have been obtained by a battery composed of a copper cartridge case, one-quarter of an inch diameter, and half an inch long, filled with salt water, and a piece of zinc wire passing through the cork which closed the open end. In another case a voltaic pile was used, consisting of a copper cent and a piece of sheet zinc of equal size, separated by blotting paper wet with acidulated water.



The microphone is so sensitive that sounds quite inaudible to the unaided ear, are magnified so as to be distinctly heard. The vibrations caused by the fleshy part of the finger, or a narrow strip of tissue paper, drawn carefully along the face of the support, produce a distinct rushing or scratching sound.

Speaking in an ordinary tone, near it, causes a sharp, rattling sound in the receiving instrument, and, in order to transmit articulate sounds, it is necessary either to speak in a whisper, or at a considerable distance from it.

It must be remembered, however, that the sounds received by the ear are no louder than when the ordinary transmitter is used: but the microphone so increases feeble sounds that they may be uttered many feet away, and be as distinctly heard as when the ordinary transmitter is held near the mouth.

Its sensitiveness can be varied to a considerable extent, by inclining it to a greater or less degree; but, thus far, the most remarkable results have been obtained by leaving it in its most sensitive condition, and removing the source of sound to a distance.

Several microphones were exhibited, most of them of very rude construction, but answering equally well with the more finished instruments. Experiments were made to illustrate their exceeding delicacy. Sounds produced by the ticking of a miniature clock, the light twang of a very fine stretched wire, the movement of a small camel's hair-brush, and whistling in a low tone in a remote portion of the building, were transmitted and distinctly heard by members and visitors, through a number of Bell telephones connected in different parts of the lecture-room.

THE MICROPHONE RELAY.

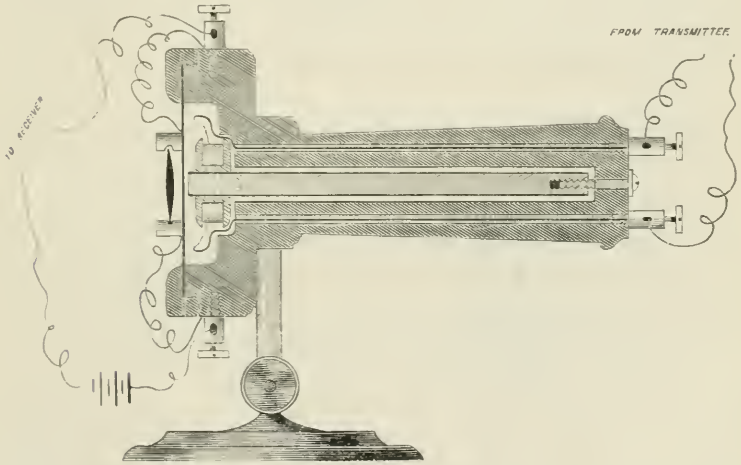
By Profs. EDWIN J. HOUSTON and ELIHU THOMSON, of the Philadelphia Central High School.

Immediately after the announcement by Prof. Bell, of his remarkable invention of the articulating telephone, the authors proposed for themselves the task of relaying this instrument. Quite a number of different arrangements were tried, but owing to the exceedingly feeble movements of the diaphragm of the receiving telephone, none of them were very successful. The discovery by Prof. Hughes, however, of the inexpressibly delicate microphone, happily afforded us the means of at last solving the problem at which we had been so long engaged.

In our application of the microphone for the relaying of the telephone, we attach a miniature microphone to the plate of the receiving telephone. The microphone so attached consists essentially of three small pieces of carbon, each being about $\frac{3}{8}$ of an inch in length. These pieces are arranged exactly as in the manner described by Prof. Hughes, viz.: one of the pieces of carbon, which is sharpened at both ends, rests vertically in small cavities near the ends of the two other pieces, as shown in Fig. 1. The two carbon supports for the third piece are cemented at their ends directly to the plate of the telephone.

The microphone so constructed is placed in the new circuit in which it is desired to repeat the message originally transmitted. The method of its operation is evident. The slight movements of the diaphragm of the receiving telephone, which are, in fact, so slight as to render them almost impossible of detection by mechanical means, are nevertheless at once recognized by the marvellously sensitive microphone, and are repeated in the new circuit as variations in the intensity of the electrical current traversing it. The message so relayed or repeated, for it is evident that the instrument can be used either as a relayer or a repeater, may be either received at once by a telephone placed in said circuit, or may be again repeated in a new circuit. By this means we believe that the distance to which a telephone message can be transmitted will be very greatly increased.

Fig. 1.



Owing to the extreme sensitiveness of the microphone, it will be necessary, in the practical application of this instrument as a relay, to carefully shield it from all extraneous sounds, which, weak though they may be, are, nevertheless, very loud when compared with those which would be produced by the feeble movements of the plate of the receiving telephone. This may be obtained in practice in several ways; as, for example, by placing the microphone relay in a box with double or treble hollow walls lined with cotton, wool, or some other non-homogeneous material: or by sinking the instrument in a pit under ground. We have found but little difficulty, however, in the trial of our instrument over a city line of some three miles in length, of obtaining the quiet necessary for the working of the instrument, although the latter was placed in a large room in the second story of a building facing a public thoroughfare, and the time of trial was shortly after midday.

The microphone, when properly constructed, has its greatest sensitiveness when the piece of carbon pointed at both ends rests in a nearly vertical position. Its electrical resistance is then at its maximum. In this position the upright carbon is resting on its extreme ends, and the cross-section of contact a minimum. So placed the slightest acoustic movement brings portions of the conical surfaces of the upright piece against the edges of the cavities, and thereby diminishes the resistance by increasing the area of the surfaces in contact. If now it be desired to diminish the sensitiveness of the instrument, it is only necessary that it be so placed, that the upright carbon be no longer supported vertically, but be slightly inclined In this position more force is required to move the upright piece, and so cause it to vary the electrical resistance. In all the microphones that we have experimented with when the upright piece was held nearly vertically, whispers or other faint sounds were distinctly transmitted, but the voice of a person standing a few feet from the instrument, and speaking as in ordinary conversation, caused such a rattling of the receiving instrument as either to render the sound unintelligible or greatly confused. In all such cases, a certain inclination could be obtained, varying slightly in each instrument, at which the rattling of the instrument entirely disappeared, and the sound was distinctly and loudly transmitted.

Fig. 2.

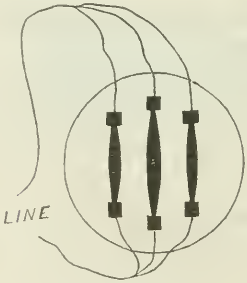
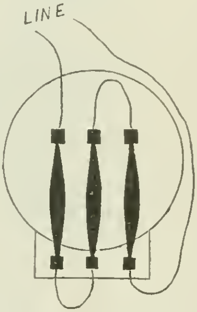


Fig. 3.



When the microphone relay is placed in a circuit whose resistance is considerable, as, for example, at the end of a distant station, we increase the sensitiveness of the instrument by attaching a number of minute microphones to the receiving diaphragm, as shown in the figures. These may be connected in series to separate battery circuits, as in Fig. 2, or in multiple arc in the same circuit, as in Fig. 3.

Since the variation in the electrical resistance of the microphone depends mainly on the upper contact of the loose piece with its support, an increased delicacy may be obtained by attaching this support directly to the middle of the diaphragm of the receiving instrument, while the lower support need not necessarily be attached to the diaphragm.

We have measured the resistance of a microphone, in which the movable piece was composed of a piece of carbon about 1¼ inches long and ¼ inch square, and find that when placed in an upright position, it has about a resistance of 50 ohms, varying, however, in a marked manner, with any sound. The same instrument, when turned at an angle of about 40° from the vertical, was found to have its resistance diminished to about 25 ohms.

It may be mentioned, as an interesting fact in regard to the microphone, that when the upright piece is placed in the position of its greatest sensitiveness, and a moderately loud sound is made near it, although such sound is only transmitted as a confused rattling, yet its resonance can, in most cases, be distinctly heard. This is, probably, the cause of the peculiar ringing sound heard when the microphone transmits mere noises, such as those produced by a person walking.

Microphone.—Du Moncel, in describing Hughes' microphone, reported some experiments of Crookes, who compared the sound of a fly enclosed in a box to the kicking of a horse. When a watch was placed upon the table, the play of the wheel-work, the strokes of the balance-wheel, and even the special sound of the metal, were all heard distinctly. Hughes is said to have transmitted, by means of his system, the most minute sounds to a distance of one hundred miles. Carbon is not the only substance which can be employed; he has obtained very good results from iron, and the effect produced by surfaces of platinum, in a great state of division, has been equal, if not superior, to that which has been obtained from the mercurized carbon.—*Comptes Rendus.* C.

Phosphorus in Iron and Steel.—Melted pig iron and iron oxide, melted in a cupola, are mixed together, by Bell, in a revolving puddling furnace, at a moderate temperature, when the phosphorus oxidizes before the carbon has been absorbed. The purified iron is then withdrawn into a furnace, in which it is changed into wrought iron or steel.—*Ber. Deutsch. Chem. Ges.* C.

Propagation of Electricity and Heat.—Cornu has investigated the application of Fourier's formulæ relative to the diffusion of heat to the propagation of electricity. He finds that there are, under certain conditions, phenomena which may be represented as electric waves moving with a constant velocity, but that there is another phenomenon, which he calls the diffusion of electric waves, which seems to vary with the simple distance rather than with the square of the distance.—*Comptes Rendus.* C.

Tale-telling Gas Tubes.—M. Izarn, at the Lycée of Clermont, noticed that he was able to hear the Morse signals from the Telegraphic Bureau and from the Artillery School, although there were no wires near enough to account for the fact. He found that there were gas tubes in the neighborhood, and he supposed that the message was conveyed by a derived current, through the intervention of the moist soil and a net-work of tubes. He satisfied himself by experiment that the phenomenon could not be explained by the telluric currents, and suggests the importance of taking proper precautions to prevent the secrets of the telegraph from being exposed in this unexpected way.—*Comptes Rendus.* C.

Influence of Light upon Cement.—Dr. Heintzel thinks that the influence of light upon cement has not hitherto been sufficiently considered. He instituted some experiments upon a quantity of cement, which he divided into three parcels, exposing parcel A to the air and full light, B to the air and diffused light, and secluding C in darkness from the air. After six months he found that A made a weak mortar, by absorbing 38 per cent. of its weight in water, and it had become crumbly; B, with 33⅓ per cent. of water, made a mortar which was too adhesive to the trowel, and it yielded up none of its water; C, with 33⅓ per cent. of water, made an excellent mortar, easily stirred and flowing, and it relinquished some of its water. After setting for twenty-eight days, the relative strength was: A, 3; B, 37·9; C, 44·6.—*Ding. Jour.* C.

Earth Currents.—Du Moncel objects to the term "telluric currents," because the currents during the day are inverse to those which are produced during the night. During the day they are directed from the telegraph line to the earth and are thermo-electric. During the night they have an opposite direction, because the dew cools the wire and produces an increased oxidation which makes the currents hydro-electric in their character.—*Comptes Rendus.* C.

Objections to "Hard Glass."—A. Lamek (*Polyt. Notizblatt*) warns chemists against the use of beakers, alembics, and other articles made of "hard glass." He was filtering a solution of phosphate of lime into a half-litre glass, when it suddenly exploded, without any perceptible cause. He had not heated the glass, neither was there any shock or change of temperature, but the glass was "shivered into a million fragments," and he was wounded in the back. C.

Defective Notes of Stringed Instruments.—Achille Dien has sent two memoirs to the French Academy, the first upon the defective notes of violins and similar instruments, and the second upon the resonance of the minor seventh, in the heavy strings of the piano. He shows that the defects are owing to secondary vibrations which are set up either by the bow or mufflers. He counteracts them by a third system of vibrations, which neutralizes the discord so effectually that the Academy has given its approval to his inventions.—*Comptes Rendus.* C.

The Equivalent of Gallium.—Boisbaudran has estimated the value of the equivalent of gallium: 1. By calcining gallo-ammoniacal alum; 2. By calcining the nitrate of gallium which is formed by a known weight of metal. The small losses of material during these two operations affect the value of the equivalent inversely, so that the mean is not perceptibly changed. His investigations lead to a maximum value of 69·97, and a minimum of 69·66, giving a mean of 69·82. After making various comparisons among the spectra of aluminium, gallium and indium on the one side, and sodium, rubidium and caesium on the other, he deduces the value 69·86, which is a little greater than that which was given by Mendelejeff for the body which he predicted, in his theoretical classification of the elements.—*Comptes Rendus.* C.

Submarine Lighting.—Barnet and Foster compress pure oxygen into a cylindrical reservoir of forged iron, under a pressure of thirty atmospheres. This oxygen is supplied by a flexible tube to an alcohol lamp provided with means for the escape of the gaseous products of combustion. This furnishes a brilliant light for a period of four hours. Heinlhe and Davis use a glass cylinder upon the diver's helmet, which contains an electric lamp of polished copper. The carbons are arranged to last for about four hours without being renewed. The whole apparatus weighs about 27 kilogrammes, and is capable of furnishing a light equivalent to 20,000 standard candles.—*Rev. Marèt.* C.

Transit of Mercury.—Among the reports of the transit which have been communicated to the French Academy, those at Ogden seem to have been the most satisfactory, sixty-eight photographs having been taken. At Montsouris the day was cloudy, and only partial glimpses of the sun could be obtained. They were, however, sufficient to show a remarkably close accordance with the predictions of the French *Connaissance des Temps.* At Toulouse, the aureole was noticed at three different times, but always without the black glass, when the thickness of the clouds allowed only a small quantity of light to escape. Great satisfaction is expressed at the confirmation of Leverrier's theory of an intra-mercurial planet, and it seems to be generally admitted that the aureole is due to terrestrial atmospheric influences.—*Comptes Rendus.* C.

Ratio of Draft to Mean Temperature.—Palamede Guzzi has investigated the mean temperature of the smoke in chimneys, and the force of draft which arises from it. By means of a manometer of special form he weighs the volume of smoke in the chimney, and thus deduces its density and temperature. He finds the formula

$$\frac{\tau_0+\tau_1}{2}=\frac{H\,\tau}{H-0{\cdot}002927\,.\,\delta\,.\,\tau},$$

in which H is the height of the chimney in metres; τ_0, τ_1, the extreme temperatures in the chimney; τ, the absolute temperature of the external air; δ, draft force, at the foot of the chimney, in millimetres of water. The greatest difficulty in the application of the formula is in the determination of δ, which may be found by extended experiments upon boilers of different types and sizes.—*Il Politecnico.* C.

Hardening of Copper and Copper Alloys.—Everitt gives the following recipe: Melt together and stir until thoroughly incorporated, copper, and from one to six per cent. of manganese oxide. The other ingredients for bronze or other alloys may then be added. The copper becomes homogeneous, harder, and tougher.—*Berg- u. Huett. Zeit.* C.

New Electric Lamp.—Reinier has exhibited a new electric lamp to the French Academy, in which he uses a small bar of carbon pressed laterally by a moving elastic contact, upon a fixed contact, and crossed by a moderate current between the two contacts. It gives clear white light with four Bunsen elements. With more powerful sources of electricity, many lamps can be kept burning, and the electric light can thus be readily divided.—*Comptes Rendus.* C.

Limits of Gaseous Combustibility.—P. Schutzenberger has experimented upon the combustibility of various mixtures of oxygen and hydrogen, or hydro-carbons. He finds that the completeness of the combustion depends upon a large number of elements, viz: the proportion of the gases, the pressure, the length of the column of gas submitted to the spark, the diameter of the tube, the initial temperature of the gas, the force, magnitude, and position of the spark, the dryness of the gas. He finds a marked tendency to nodes, dividing the column into two or four equal parts, across which the combustion can pass only with difficulty.—*Soc. d'Encour.* C.

Complementary Colors.—Chevreul has lately communicated to the French Academy some experiments upon the influence produced upon the appearance of colored objects which are rotating, when they are compared with similar objects in repose. He considers them as confirming all the experiments upon which he founded his laws of simultaneous, successive, and mixed contrasts of color. At a time when the industrial and fine arts have found the necessity of testing the susceptibility of their apprentices to delicate shades of color, and especially when the science of signalling is assuming so great importance, he considers that such experiments deserve special attention, and suggests that by means of spinning tops, very delicate and ready tests can be provided.—*Comptes Rendus.* C.

St. Gothard Tunnel.—A singular depression has been lately noticed in the strata which are traversed by the St. Gothard Tunnel. Some geologists think that it indicates a subterranean sea in the interior of the mountain. A late report of the inspector of the works asserts that the irregularity has ceased, and the perforation has resumed its regular course. On the southern side there is an advance of three metres per day. It is a little less at the northern extremity, where the tunnel has not yet emerged from the serpentine, although it has traversed that hard rock for double the distance that the geologists anticipated.—*Les Mondes.* C.

Music and Acoustics.—Helmholtz, Blaserna, and some other eminent savants, have thought that there might be an advantage in confining music to exact combinations, and in renouncing the temperaments adopted in musical practice. Helmholtz even made a harmonium, so constructed that he could play, at will, either with the scientific or with the tempered scale. Although he obtained some remarkable results in the scientific gamut, Hirn opposes a change which would so greatly reduce the resources of the art. He enters upon an inquiry whether science can explain the powerful action which sounds and their musical combinations produce upon us. Faye regards this novel investigation as one of profound interest, and proposes to extend it to the Oriental and other forms of music, which are founded upon principles entirely different from our own, without diminishing their action on the human organism.—*Comptes Rendus.* C.

Submarine Telephone.—The first use of the telephone under water in this country has been recently made, in connection with submarine examinations in Boston Harbor. The character of these examinations was such that it would have been impracticable to undertake them without its aid, as almost constant communication was necessary between the diver and his assistant in the boat. The telephone used under water has a metallic case so modified in form as to occupy but little space, and is attached by screws to the inside of the diver's helmet in such a position that either the ear or the mouth can be applied to it. In the boat, a single telephone of the ordinary form is used. The insulated copper wire connecting the two telephones passes through the air-pump box. Between the pump and the diver's helmet it is wound spirally around the air hose, the wire and hose being then tightly wound around with canvas for protection from injury. At first two connecting wires were used, the second not necessarily insulated, but it has since been found better to substitute for the second wire a shorter wire connecting the upper telephone with a copper plate fastened under the boat.—*Engineering News.*

*

Book Notice.

HOUSE DRAINAGE AND WATER SERVICE IN CITIES, VILLAGES AND RURAL NEIGHBORHOODS, with incidental consideration of causes affecting healthfulness of dwellings. By James C. Bayles, Editor of the *Iron Age* and the *Metal Worker*. Large 8vo., pp. 360. Price, $3.00. David Williams, N. Y., 1878.

This work takes up the subject of drainage and water-supply where the professional engineer usually leaves them, and treats more particularly of those points which are under the control of the individual house-owner, and those connected with the house-building trades, touching only incidentally upon the subjects of town drainage and public water-works. It is not in any sense a manual for the plumber, but it is a clear and full exposition of the hygienic principles involved, and of the best modes and materials to be used in maintaining the healthfulness of our dwellings.

Chapter I treats, in a general way, of Hygiene in the practical relation to health, pointing out the fearful ravages of diseases in the middle ages, arising from a disregard of the simplest requirements of health, and shows that with the great progress since needed, sanitary science is still in its infancy.

Chapter II discusses the production and nature of *sewer gas*, its action in producing disease, and the different theories upon the subject of sewer gas poisoning. The importance of sewer ventilation is forcibly considered, together with the methods employed for that purpose.

The next five chapters treat upon the mechanical portion of the plumber's trade, and cover every detail of pipes, traps, seals, tanks, closets and household fixtures, with numerous examples of the most approved practice, and some of bad practice.

Great stress is laid on the importance of properly arranging all these connections of the water-closet, and eighteen pages are given to that subject alone.

Chapter VIII, on the Chemistry of Plumbing, is a valuable contribution to sanitary science, containing a discussion of the action of the various substances found in solution in water; on the materials used in plumbing, and of the best known methods of preventing results deleterious to health.

Chapter IX, on Elementary Hydraulics applicable to plumbing, contains some tables and other information in regard to the pressure and flow in pipes, and the raising and storing of water, calculated to be of great use to the practical plumber.

The next two chapters, on Sanitary Construction and Drainage of Country Houses; water-supply in country districts, particularly deserve the attention of those living in districts remote from public drainage and water works.

Chapter XII, on the Sanitary Care of Premises, treats mainly on cleanliness, and on the nature and use of disinfectants, and pertains more to housekeeping than to plumbing.

Chapter XIII, on the Plumber and his work, discusses the relation between the plumber, and the architect, the builder and the householder, and, in a certain sense, is a plea for the former. While pointing out many of the shortcomings of the practical plumber, he also shows that the fault does not lie entirely with him, but that each of the others is responsible in a considerable degree in bringing about a condition of affairs which give us much inferior plumbing work; cheap, perhaps, in dollars, but fearfully expensive in health.

The thorough and comprehensive character of this work must commend it to all interested in the mechanics of hygiene.

The mechanical execution is excellent, being printed on heavy tinted paper, in clear type, with good illustrations; and a copious index renders the contents readily accessible to the reader. *

Franklin Institute.

Hall of the Institute, June 19th, 1878.

The stated meeting was called to order at 8 o'clock P. M., the Vice-President, J. E. Mitchell, in the chair.

There were present 206 members and 77 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting 2 persons were elected members of the Institute; and the following donations made to the Library:

Pennsylvania Archives, Second Series. Published under direction of M. S. Quay, Secretary of Commonwealth. Edited by John B. Linn. Vol. 6. 1877. From Hon. J. B. Linn.

Reports of Commissioner of Patents, U. S. Patent Office. Mechanical, 1849-50, 1855, Parts 1 and 2; Agricultural, 1851, 1854, and 1856. From W. P. Tatham.

Sketch of the origin and progress of the U. S. Geol. and Geog. Survey of the Territories. Wash., 1877
From F. V. Hayden, Geol. in Charge.

Geological Survey of Hokkaido; a general report on the Geology of Yesso; by Benj. S. Lyman. Tokio, 1877. From the Author.

Iron-works of the United States; a Directory of the furnaces, rolling mills, etc. Phila., 1876.
From the Am. Iron and Steel Asso., through E. Hiltebrand.

Bulletin of the U. S. Geol. and Geog. Survey of the Territories. No. 1, Vol. 4. Wash., Feb. 5, 1878.

Report of the U. S. Geol. Survey of the Territories. F. V. Hayden, Geol. in Charge. Vol. 7, Tertiary Flora, by Leo Lesquereux.

U. S. Geog. and Geol. Survey of the Rocky Mountain region. J. W. Powell in Charge. Vol. 3, Contributions to North American Ethnology, by S. Bowers. Wash., 1877.
From the Secretary of the Interior.

Pennsylvania and the Centennial Exposition: comprising the preliminary and final reports of the Penna. Board of Centennial Managers, made to the Legislature, at the sessions of 1877–78. 3 parts in 2 vols. Philadelphia, 1878.
From Am. Iron and Steel Asso., through E. Hiltebrand.

Annual report of the operations of the United States Life-Saving Service, for the fiscal year ending June 30th, 1877. Washington, 1877. From Secretary of the Treasury.

Sixth annual report of the Board of Directors of the Zoological Society of Phila., read April 25th, 1878. From the Society.

Salisbury Iron. Its composition, qualities and uses. Barnum Richardson Company, 1878. From the Company.

Almanaque Nautico para, 1875. Calculado de orden de la superioridad en el Instituto y observatorio de marina de la Cindatt de San Fernando. Madrid, 1878. From the Observatory.

Classified and descriptive catalogue of the collection of the Products and Manufactures of British India. Compiled by J. Forbes Watson, Philadelphia. From the Penna. Museum and School of Industrial Art.

Specifications and drawings of patents, issued from the United States Patent Office, for November, 1877.
From the U. S. Patent Office.

Thirty-fifth annual report of the Managers of the State Lunatic Asylum, Utica, N. Y., 1877. From the Managers.

Metropolitan Museum of Art. Seventh annual report of the Trustees of the Association. May, 1877. From the Trustees.

Ohio Mechanics' Institute, of Cincinnati. Forty-ninth annual report of the Board of Directors. 1876–77. From the Institute.

Annual report of the Chief Engineer of the Water Department of Philadelphia, for 1875. From the Chief Engineer.

Arguments before the Committee on Patents, of the Senate and House of Representatives. Washington, 1878.
From Chief Clerk of Patent Office, through Hubert Houson.

Report of the Commissioner of Fish and Fisheries, for 1875–76. Part 4. Wash., 1878. From the Smithsonian Institute.

Report of the Twelfth Industrial Exhibition, under the auspices of the Mechanics Institute, of the City of San Francisco. 1878.
From the Institute.

Report of the Committee on the Metric System of Weights and Measures. April, 1878. Philad'a.
From the Engineers' Club, through Chas. E. Billin, Secretary.

Atlas to accompany the report of the United States Geological Exploration of the fortieth parallel, C. King, Geol. in charge.
From the Chief of Engineers.

The Secretary's report embraced D. K. Miller's six-tumbler padlock, Geo. R. Moore's closet ventilator, Jos. L. Parry's open-float steam-trap, and the microphone of Prof. Hughes.[i]

Prof. E. J. Houston gave a description of an application of the microphone to relaying the telephone, devised by himself and Prof. E. Thomson.[ii]

On motion, the meeting adjourned.

J. B. Knight, *Secretary.*

Errata.—On page 432, Vol. CV, in the last line of preamble to the Resolution in memory of Prof. Henry, read 1878 instead of 1875.

---

[i] See page 57.

[ii] See page 60.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CVI. AUGUST, 1878. No. 2.

THE Franklin Institute is not responsible, as a body, for the statements and opinions advanced by contributors to the JOURNAL.

EXPANSION OF STEAM IN THE STEAM-ENGINE.

An Investigation of the Experiments made with the Screw Machinery of the French Naval Steamer CHER *to Determine the Economic Efficiencies of Different Measures of Expansion for Steam.*

By Chief Engineer ISHERWOOD, U. S. Navy.

[Continued from Vol. lxxvi, page 12.]

Before commencing an experiment, the engine was worked for one hour under the intended conditions, so that it might be in proper harmony with them when the experiment began. At the end of an experiment great care was taken to leave the water in the boilers at exactly the same level as at the commencement, and under the same steam pressure. The sacks of coal were delivered on the fire-room floor as required.

One experiment was made each day, but there is nothing in the original data to show how long it continued; probably the experiments averaged about four hours each. This is too short a time to give the coal consumption with the accuracy necessary for the purpose, although the closest attention was given to have the fires in the same condition and of the same thickness at the beginning and end of an experiment, for it is evident that as the estimation had to be made by the eye, considerable inaccuracy was unavoidable, and that the shorter the time among which the error was to be divided, the greater it became. This was not the case, however, with the feed-water measurement, which may be depended on as very exact, and as it alone is taken for the measure of the cost of the power in the different experiments, the coal expenditure is of use only as giving the economic vaporization by the boiler.

It is regretable that the details and data of these experiments were not more fully given, and particularly that the experiments were not of longer duration. With such short experiments, the indicator diagrams, instead of being taken half hourly, should have been taken every five minutes, and the data should have included as measured from them not only the quantities given in the table, but a number of others; such, for example, as the pressure of the steam in the cylinder at the commencement of the stroke of the pistons, at the point of cutting off the steam, and at the end of the stroke of the pistons. The back pressure against the piston of the middle cylinder should have been given as well as that against the pistons of the end cylinders which is given. The temperatures of the engine room, fire room, atmosphere, sea water and feed water, should have been given as well as the height of the barometer. The weight of refuse from the coal should have been noted also.

Notwithstanding these omitted quantities, which were desirable for many purposes besides those that the experimenters had immediately in view, the experiments are of great value, being on the most important facts in steam engineering, namely, the relative economic efficiencies of different measures of expansion for steam; and although they are not comparable for completeness, extent and variety to the writer's prior ones on the same subject, and although they add nothing new to his discoveries, yet they are of consequence—and therein lies their true importance—as confirmatory of the accuracy of his facts and the correctness of his deductions, and none the less so, as having been made by foreign engineers of the highest reputation, far removed from the interested and partisan efforts which assailed the unwelcome truth here.

DISCUSSION OF THE EXPERIMENTS.

The first point to investigate is the accuracy of the experiments according to their own evidence. They were made in a very large enclosed basin, free from tidal influence; and the vessel occupied the same position throughout. Under these conditions, the same development of power should give the same number of revolutions to the screw in equal time; and with unequal revolutions in equal time, the *net* power should be in the ratio of the cubes of those revolutions. The first postulate is self-evident, and the second has been proved experimentally true by a vast number of trials in a great variety of circumstances.

In experiment A, 66·34 revolutions of the screw per minute required 448·758 net horses-power, while in experiment O, 66·27 revolutions of the screw per minute required 462·756 net horses-power, a discrepancy of $\left(\frac{462{\cdot}756 - \overline{448\,758 \div 1{\cdot}003 \times 100}}{462{\cdot}756} =\right)$ 3·32 per centum of the greater number.

In experiment B, 61·37 revolutions of the screw per minute required 330 330 net horses-power, while in experiment J, 61·25 revolutions of the screw per minute required 336·692 net horses-power, a discrepancy of $\left(\frac{336{\cdot}692 - \overline{330\,330 \div 1\,006} \times 100}{336{\cdot}692} =\right)$ 2·48 per centum of the greater number.

In experiment E, 58·78 revolutions of the screw per minute required 302·722 net horses-power, while in experiment C, 58·14 revolutions of the screw per minute required 281·041 net horses-power, a discrepancy of $\left(\frac{302{\cdot}722 - \overline{281{\cdot}041 \times 1{\cdot}0333} \times 100}{302{\cdot}722} =\right)$ 4·07 per centum of the greater number.

In experiment N, 53·68 revolutions of the screw per minute required 232 169 net horses-power, while in experiment F, 53·70 revolutions of the screw per minute required 219·063 net horses-power, a discrepancy of $\left(\frac{232{\cdot}169 - 219\,063 \times 100}{232\,169} =\right)$ 5·64 per centum of the greater quantity.

In experiment L, 51·25 revolutions of the screw per minute required 191·018 net horses-power, while in experiment G, 51·10 revolutions of the screw per minute required 189·758 net horses-power, a discrepancy of $\left(\frac{189.758 + 1\cdot009 - 191\cdot028 \times 100}{191\cdot466} = \right) 0\cdot23$ per centum of the greater quantity.

A correction of the power developed in the different experiments, may be made by ascertaining from the mean of all in the ratio of the cubes of the number of revolutions made by the screw per minute, the net horses-power required to make, say, 60 revolutions of the screw per minute, and then from it determining in the same ratio the net horses-power required for the different experimental revolutions of the screw per minute.

The following table shows the net horses-power required to give the screw 60 revolutions per minute, as computed from the tabular net horses-power developed by the engine modified in the ratio of the cube of 60 to the cube of the tabular number of revolutions made by the screw per minute. The discrepancies from the mean of all, which is 314·656 net horses-power for 60 revolutions of the screw per minute, are probably due to the too small number of indicator diagrams taken during each experiment:

Designation of Experiment.	Net horses-power required to give the screw 60 revolutions per minute.
A,	331·946
B,	308·547
C,	308·904
D,	311·339
E,	317·870
F,	305·570
G,	307·151
H,	305·325
J,	316·350
L,	306·462
M,	305·980
N,	324·168
O,	340·914
Mean of all,	314·656

From the mean of the above determinations, namely, 314·656 net horses-power for 60 revolutions of the screw per minute, the net horses-power in the following table have been calculated for the experimental number of revolutions made per minute, by modifying the 314·656 in the ratio of the cube of 60 to the cube of the experimental number of revolutions made by the screw per minute.

The indicated horses-power in the following table have been obtained for the experimental number of revolutions of the screw per minute, on the supposition that the pressure required to work the unloaded engine and shafting was 1·5 pounds per square inch of all the pistons, and adding to the corresponding power the corrected net horses-power as above obtained.

The total horses-power in the following table have been obtained for the experimental number of revolutions of the screw per minute by adding to the corrected indicated horse-power, as above obtained, the experimental horses-power required to overcome the back pressure against the pistons.

Designation of the Experiment.	Corrected net Horses-power.	Corrected indicated Horses-power.	Corrected total Horses-power.
A,	425·289	468·636	493·162
B,	335·871	375·972	394·942
C,	286·274	324·264	349·151
D,	226·716	262·373	288·965
E,	295·871	334·508	357·621
F,	215·577	250·665	274·338
G,	194·294	227·684	248·935
H,	162·551	193·969	220·416
J,	334·888	374·910	398·247
L,	196·125	229·617	251·647
M,	309·684	348·680	372·580
N,	215·357	250·433	269·405
O,	427·014	455·883	522·318

The exact quantity of heat remains to be determined which was consumed in the production of the above horses-power. The weight of feed-water pumped into the boilers per hour may be considered nearly accurate; and, as the steam was more or less superheated when entering the valve-chest of the middle cylinder, there was doubtless no water carried over by foaming or priming. It is probable that the able experimenters assured themselves before commencing of the tightness of the pistons and steam-valves, and that there was no leakage of steam from the valve-chests or cylinders to the condenser: the small quantity of feed-water required per hour per total horse-power in some of the experiments is evidence against such leakage. The engine being a compound one, any leakage from the middle cylinder would be intercepted by the end cylinders, and its effect correspondingly reduced; while the pressure in the end cylinders when the large measures of expansion were used, was so low that there was but little danger of leakage from them. Had there been leakage, however, of this kind, it would have affected the smaller developments of power more than the greater ones, increasing disproportionally the cost of the power with the larger measures of expansion, those measures being accompanied by smaller developments of power under the experimental conditions. The only remaining source of error was water-leakage from the boilers, in which case, other things equal, the economic vaporization of the coal should have appeared the greatest during the experiments in which the smallest powers were developed by the engine. The fact, however, was the reverse, the economic vaporization of the coal, as a rule, increasing with increasing power; and notwithstanding that, as a rule, the increasing powers were accompanied by increasing rates of combustion. There was, then, no error from this cause, and the quantity of heat in the steam entering the valve-chest of the middle cylinder can be exactly determined by multiplying the weight of feed-water consumed per hour by the number of Fahrenheit units of heat imparted to this water in each experiment, taking for that purpose the total heat in Fahrenheit units of steam of the pressure on line 7 of the large table of experimental results, (the pressure it had on entering the valve-chest of the middle cylinder) less the number of Fahrenheit units of heat in the feed-water when it entered the boiler; and adding to the quantity of heat thus obtained the number of Fahrenheit units imparted to the steam by superheating. The latter quantity is ascertained by multiplying the weight of feed-water pumped into the boiler per hour, by the number of Fahrenheit degrees of superheating (line 15 of the large table of experimental results) possessed by the steam when it entered the valve-chest of the middle cylinder, and then multiplying that product by 0·4805—the specific heat of steam compared with that of water as unity.

The quantities of heat thus obtained, expended per hour in the production of power during each experiment, are as follows:

Designation of the Experiment.	Fahrenheit units of heat consumed per hour in the vaporization of the feed-water.	Fahr. units of heat consumed per hour in the super-heating of the steam.	Fahrenheit units of heat consumed per hour in the production of the power.
A	13262966·228	63959·921	13326926·149
B	9376822·247	63687 872	9440510·119
C	8059253·354	36497 978	8095751 332
D	6936693·968	52824 343	6989518·311
E	9681923·445	90020 076	9771943 521
F	6659848·515	58282·713	6718131·228
G	5941986 380	56752·971	5998739 351
H	5127838 940	46373·207	5174212·147
J	10764053 730	98160 868	10862214·598
L	6740323·936	86282·488	6826606·424
M	9400219·647	78432·605	9478652·252
N	8012928·352	54756 794	8067685·146
O	18867096·310	00000·000	18867096·310

The quantities in the last column of the above table represent accurately the relative quantities of coal required to be consumed in the different experiments to produce the net, indicated and total horses-power in the table immediately preceding the one above. The quotients of their division into the quantities in the last column of the above table, expresses their relative cost in weight of coal consumed per hour.

The results of such divisions will be found in the following table :

Number of times the steam was expanded.	Designation of the Experiment	Cost of the net horse-power in Fahrenheit units of heat consumed per hour.	Cost of the indicated horse-power in Fahrenheit units of heat consumed per hour.	Cost of the total horse-power in Fahrenheit units of heat consumed per hour.
2·26	A	31336·165	28437 692	27023·425
3·21	B	28107·547	25109 609	23903·536
3·78	C	28279·730	24966·544	23186·963
4·59	D	30829·400	26639·625	24188·114
2·26	E	33027·717	29212·884	27324·859
3·21	F	31163·488	26801·234	24488·519
3·78	G	30874·548	26346·776	24097·613
4·59	H	31831·315	26675·459	23474·757
2·26	J	32435·365	28792 859	27275·069
2·26	L	34807·426	29730·405	27127·708
2·26	M	30607·497	27184·388	25440·583
2·26	N	37461·908	32214·944	29946·308
1·26	O	44183·789	41166·475	36121·857

The quantities in the last column of the above table show the relative cost in coal, when burned under equal economic conditions, of the total horse-power for the different experiments. Now the total horses-power measures the entire mechanical work done by the steam, both internal and external, and is the true quantity to be taken as the effect produced when the question is how the cost of steam-power in fuel is affected by the measure of expansion with which the steam is used; and independently of what fraction of this total horses-power may be utilized commercially in the cases of the different measures of expansion.

Experiments A to H, both inclusive, show that from an expansion of, say, three times to an expansion of, say, five times, the measure of expansion with which the steam is used does not affect its economy in the production of the total horses-power; and that, too, with superheated steam used in a compound engine but without steam-jacketed cylinders. Consequently, for steam of all measures of expansion between three and five times, used in the same cylinder, with the same speed of piston and with the same development of indicated horse-power by the same indicated pressure, but with unequal initial pressure, this pressure being less and less as the steam is less and less expanded, the indicated horse-power would be obtained for the same quantity of heat imparted per hour to the water in the boiler. And the same remark applies to the net horse-power, *mutatis mutandis.*

A further corollary is, that for equal developments of power with equal initial pressure in the cylinder and equal piston-speed, but with cylinders having areas in inverse proportion to the mean indicated pressure which the different measures of expansion would produce under these conditions, the indicated horse-power would be obtained for less heat expended per hour with the measure of expansion three times than with any greater measure up to five times. And the same remark applies to the net horse-power, *mutatis mutandis;* but with this modification, that the expenditure of heat with the steam expansion of three times, relatively to the heat expenditure with the greater measures of expansion, would be less to produce it than in the case of the indicated horse-power.

Experiments E, F, G, H are duplicates of experiments A, B, C, D, with the exception that they were made with a lower initial cylinder pressure, and with consequently less mean pressures upon the piston, and less speeds of piston. As the total horse-power was obtained for the same expenditure of heat per hour in both sets of experiments for the same measure of expansion, it follows that the economy was not influenced by the speed of the piston when that speed was accompanied with the corresponding mean total pressure. Nor was the economy influenced by the mean total pressure when accompanied with the corresponding piston-speed.

The net horse-power and the indicated horse-power in experiments E, F, G, H, were obtained with the greater expenditure of heat per hour, than in experiments A, B, C, D, because the high back-pressure against the piston and the pressure required to work the engine, *per se*, being the same in both sets of experiments, while the mean total pressure was less in experiments E, F, G, H, owing to the less initial cylinder pressure, a less fraction of the total pressure was utilized as net and indicated pressures.

Experiments I (same as A), J, K (same as E), and L, were made with the same measure of expansion (2·26 times) but with continually decreasing cylinder pressures and speeds of piston. The heat expenditure per hour for the total horse-power was nearly constant, showing, as in the previous experiments, that it was not influenced by the speed of piston when accompanied by a corresponding mean total pressure, the engine working against resistances increasing and decreasing as the square of the speed of the piston increased or decreased. But the expenditure of heat per hour for the net and indicated horse-power increased with each decrease of the initial cylinder pressure, owing to the causes stated in the immediately preceding paragraph.

The fact, conclusively shown by all these experiments that, within their limits, the economy of the net and indicated horse-powers, after a very moderate measure of expansion is reached, mainly depends on the ratio of the sum of the back-pressure and the pressure required to work the unloaded engine, to the mean total pressure on the piston, is a strong reason for the use of the maximum total pressure practicable, or for the use of the highest possible boiler pressure, independently of the fact that with steam of higher pressures the product of the pressure into its volume is greater with a given expenditure of heat than with steam of lower pressures, but it must be remembered that the gain due to this cause continually decreases as the total pressure increases, because the back-pressure and pressure required to work the unloaded engines are constant and uninfluenced by the total pressure. On the other hand, the losses by leakage, by external radiation, and by cylinder interior condensation, for equal development of power, increase with increased total pressure, so that a point is soon reached where the gains and losses balance, to go beyond which is to experience an economic loss instead of gain. This point is only determinable by experiment, like every other physical problem.

Experiments M and N were made to show the effect of using the steam much throttled. That a gain may be thus obtained is very certain in the two cases of the steam having been used with a less measure of expansion than what corresponds to the maximum economy, or having been drawn from a boiler with too little steam room. In the former case, with equal mean total pressure, as throttling the steam increases to a certain degree the measure of expansion with which it is used, an economic gain will follow: in the latter case, the effect is to increase the steam room relatively to the bulk of steam drawn out per stroke of piston, and so prevent the economic loss due to the priming or foaming over of water from the boiler to the cylinder. As the steam in these two experiments was expanded 2·26 times by the valve-gear and compounding of the cylinders, but little or no gain could be expected from any increase in that direction; and as it entered the cylinder considerably superheated, there could have been no foaming or priming to be prevented. Under these circumstances, no gain from the throttling could be expected. The mean cost of the total horse-power in Fahrenheit units of heat consumed per hour when the steam was expanded 2·26 times, was, for the four experiments in which it was used without throttling 27,188; and for the two experiments in which it was used with throttling 27,693.

Experiment O was made with only the two end cylinders working as simple engines, that is, not compounded. The steam was saturated, that is, it entered the cylinders without being superheated; and it was expanded only 1·26 times. In all respects the steam was used in this experiment under strongly opposed conditions to those under which it was used in the preceding ones. The result was that the total horse-power cost 36,122 Fahrenheit units of heat expended per hour.

In the six preceding experiments in which superheated steam was used in compounded cylinders with measures of expansion varying from, say, three to five times, the mean cost of the total horse-power in Fahrenheit units of heat, was 23,890; there was a consequent economic gain obtained by the combined effect of using superheated heat with the most economical measures of expansion in an unjacketed compound engine of $\left(\frac{36{,}122 - 23{,}890 \times 100}{36{\cdot}122} = \right)$ 33·86 per centum over using saturated steam in a simple engine and with scarcely any expansion.

The mean results from all the experiments, of the vaporization of water in the boilers by the coal, are as follows:

Pounds of coal consumed per hour per square foot of grate surface,	12·4889
Pounds of coal consumed per hour per square foot of heating surface,	0·4858
Pounds of water that would have been vaporized by one pound of coal, had it been supplied at the temperature of 100 degrees Fahrenheit and vaporized under the pressure of 29·92 inches of mercury,	8·3660
Pounds of water that would have been vaporized by one pound of coal, had it been supplied at the temperature of 212 degrees Fahrenheit and vaporized under the pressure of 29·92 inches of mercury,	9·3436

The coal used was the briquettes d'Anzin, with less than 4 per centum of refuse.

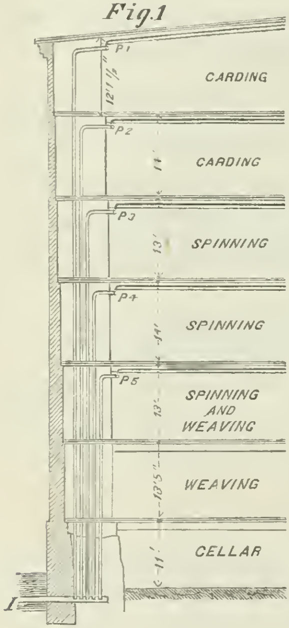
Sun Spots and Magnetism.—M. Faye has re-examined the data upon which Wolf founds his sun-spot period of 11·11 years, and also those upon which Lamont, Loomis and Braun base their magnetic period of 10·45 years. He concludes that the supposed identity of the two periods is inadmissible, and that the accordance for some years back is merely accidental. The two periods exactly corresponded about the year 1860, and the deviation during the past 18 years has been so slight that it is not strange that observers should have regarded the correspondence as a permanent one. A collection of favorable circumstances, which is reproduced every 176 years, has caused this close connection of the two phenomena. Such occasional accidental coincidences are by no means rare in the history of science. A few years ago a similar one was noticed between the sun spots and the vector-radii of Jupiter.—*Comptes Rendus.* C.

THE PROBLEM OF PERFORATED PIPES AS APPLIED TO SPRINKLERS.[1]

By J. P. FRIZELL, C. E., Boston.

A system of perforated pipes, called "sprinklers," has latterly been introduced into cotton mills for the purpose of preventing the spread of fires. The usual disposition of such pipes is indicated by Figs. 1 and 2, the former of which is a vertical section, and the latter a half plan of the Merrimack Company's Mill, No. 2, at Lowell. Each story, provided with sprinklers, has one or more vertical standpipes, communicating with the reservoir main, and controlled by valves so located as to be accessible in case of fire. Each of these standpipes communicates with a horizontal main, P_1, P_2, etc., Fig. 1, located at the side of the mill, and immediately below the beams of the overlying floor, running, generally, lengthwise of the mill. A series of smaller pipes, a_1, a_2, a_3, b_1, b_2, b_3, etc., issue from this latter at right angles, running across the mill, close under the ceiling, between the beams. Their distance apart is generally about 8 feet, being governed by the spacing of the floor-beams, windows and pillars of the mill.

Fig.1



---

[1] An appendix to a report made by the writer, to Mr. James B. Francis, agent of the proprietor of locks and canals on Merrimack River. One of that gentleman's duties is the supervision of the mutual insurance organization of the manufacturers of Lowell, in which capacity he has control of the means of extinguishing fires. Contemplating a considerable extension of the system of perforated pipes, he employed the writer during the past winter to compute the quantity of water required for an entire mill, no practical method of performing such computations having been previously known. The method pointed out has been adopted by Mr. F., and is thought worth printing, for the information of the profession and others interested. The same problem occurs in other cases. The immense lock now in process of construction at Sault Ste. Marie, is to be filled through a great number of small openings from a culvert under the floor. The computation of the time required for filling this lock, involves precisely the same principles as the above problem.

They are provided with minute orifices, 6 to 12 inches apart, located alternately on opposite sides, and so disposed as to throw the water upward and outward. The diameter of the pipes, at every part of the system. is varied according to the number and size of orifices to be supplied, from 6 or 8 inches in the standpipes, to ¾ or ½ inch in the perforated pipes near their extremities. The proper proportioning of such a system and its accessories, requires a knowledge of the quantity of water discharged. This involves a hydraulic problem of considerable intricacy, viz.: to find the relations of pressure, velocity, diameter of pipes, size and spacing of orifices at every point of this vast system. We will first consider the simplest case of a pipe of uniform diameter, with equidistant orifices of equal size:

Let the orifices be numbered 1, 2, 3, etc., n, commencing with the final orifice.

Let H_1, H_2, H_3, etc., H_n, represent the head acting at the orifices 1, 2, 3, etc., n.

Let q_1, q_2, q_3, etc., q_n, represent the discharge from the orifices 1, 2, 3, etc., n.

Let Q_1, Q_2, Q_3, etc., Q_n, represent the quantity of water passing between 1 and 2, 2 and 3, etc., $n - 1$ and n.

Let h_1, h_2, h_3, etc., h_n, represent the loss of head between 1 and 2, 2 and 3, etc., $n - 1$ and n.

The discharge at any orifice is expressed by a formula of the form $q = c\sqrt{H}$, in which c involves the area of the orifice, the accelerative force of gravity and another constant. The loss of head between two consecutive orifices is expressed by a formula of the form $h = bQ^2$, in which b involves the distance separating the orifices, the diameter of the pipe and another constant. We have, then:

$$q_1 = c\sqrt{H_1}.$$

$$Q_1 = q_1.$$

$$h_1 = b\,Q^2 = b\,(c\sqrt{H_1})^2 = b\,c^2\,H_1.$$

$$H_2 = H_1 + h_1 = H_1\,(1 + b\,c^2),$$

$$q_2 = c\sqrt{H_2} = c\sqrt{H_1}\sqrt{1 + b\,c^2}.$$

$$Q_2 = Q_1 + q_2 = c\sqrt{H_1}\,(1 + \sqrt{1 + b\,c^2}.)$$

$$h_2 = b\,Q_2^2 = b\,c^2\,H_1\,(1 + \sqrt{1 + b\,c^2})^2.$$

$$H_3 = H_2 + h_3 = H_1\,[1 + b\,c^2 + b\,c^2\,(1 + \sqrt{1 + b\,c^2})^2].$$

$$q_3 = c\sqrt{H_3} = c\sqrt{H_1}\sqrt{1 + b\,c^2 + b\,c^2\left(1 + \sqrt{1 + b\,c^2}\right)^2}.$$

$$Q_3 = Q_2 + q_3 = c\sqrt{H_1}\left[1 + \sqrt{1 + b\,c^2} + \sqrt{1 + b\,c^2 + b\,c^2\left(1 + \sqrt{1 + b\,c^2}\right)^2}\,\right]$$

$$h_3 = b\,Q_3^2 = b\,c^2 H_1\left[1 + \sqrt{1 + b\,c^2} + \sqrt{1 + b\,c^2 + b\,c^2\left(1 + \sqrt{1 + bc^2}\right)^2}\,\right]^2$$

$$H_4 = H_3 + h_3 = H_1$$

$$\left[1 + b\,c^2 + b\,c^2\left(1 + \sqrt{1 + b\,c^2}\right)^2 + bc^2\left[1 + \sqrt{1 + bc^2} + \sqrt{1 + bc^2 + bc^2\left(1 + \sqrt{1 + bc^2}\right)^2}\,\right]^2\right]$$

$$q_4 = c\sqrt{H_4} = c\sqrt{H_1}$$

$$\sqrt{1 + b\,c^2 + b\,c^2\left(1 + \sqrt{1 + b\,c^2}\right)^2 + b\,c^2\left[1 + \sqrt{1 + b\,c^2} + \sqrt{1 + b\,c^2 + b\,c^2\left(1 + \sqrt{1 + bc^2}\right)^2}\,\right]^2}$$

$$Q_4 = Q_3 + q_4 = c\sqrt{H_1}$$

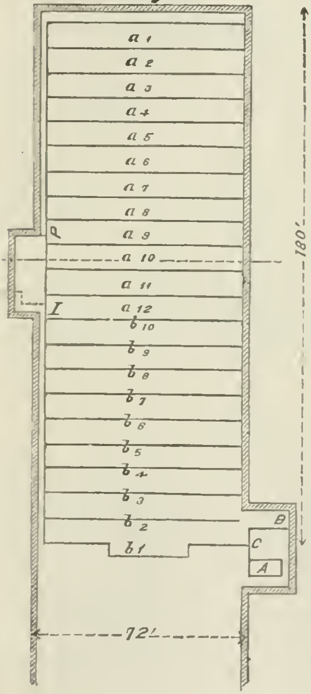
$$\left[\begin{array}{c} 1 + \sqrt{1 + b\,c^2} + \sqrt{1 + b\,c^2 + b\,c^2\left(1 + \sqrt{1 + b\,c^2}\right)^2} + \\ \sqrt{1 + b\,c^2 + b\,c^2\left(1 + \sqrt{1 + bc^2}\right)^2 + b\,c^2\left[1 + \sqrt{1 + bc^2} + \sqrt{1 + bc^2 + b\,c^2\left(1 + \sqrt{1 + bc^2}\right)^2}\,\right]^2} \end{array}\right]$$

This is sufficient to show the utter hopelessness of an attempt to express the discharge in an algebraic formula. Each value of Q occupies more than double the space of the preceding, so that for a pipe of 100 orifices, the discharge would be expressed by a formula requiring not less than 25 figures to denote its length in miles.

Nevertheless, certain facts of great importance to the inquiry become apparent upon an attentive consideration of the above series of equations. It is important, first, to note the law of the formation of the formulas for H and Q. Each value of H consists of H_1, multiplied by a constant. This constant consists of a series of terms, of which the first is unity; the second is $b\,c^2$ times the square root of the first; the third is $b\,c^2$ times the square of the sum of the first, and square root of the first and second; the fourth is $b\,c^2$ times the square of the sum of the first, the square root of the first and second, and the square root of the first, second and third, etc. The value of Q consists of $c\sqrt{H_1}$ multiplied by a constant consisting of a series of terms. Any term in this series is found from the preceding terms, by placing under the radical sign the square of the immediately preceding term, plus bc^2 times the square of the sum of all the preceding terms. We can thus write the successive values of Q or H, without reference to any other element of the problem. The expression for each succeeding orifice is formed by adding to the coefficient of H_1 or $c\sqrt{H_1}$, a term consisting of a certain combination of the preceding terms. When we come to a change in the diameter of the pipe, it is only necessary to make the proper change in the value of b in the expressions for the ensuing orifices. A similar remark applies to a change in the size or spacing of the orifices.

Since the head, acting on any orifice, consists of H_1 multiplied by a constant, it follows that the head at the origin of a pipe bears a constant proportion to that at the final orifice or any other orifice. An increase of the head at one point implies a proportional increase at all other points. The head at the origin of the perforated pipes a_1, a_2, a_3, etc., Fig. 2, increases as you approach the source of supply, I, in consequence of the loss of head in the supplying main, P. A proportional increase occurs at the final orifices.

Fig. 2



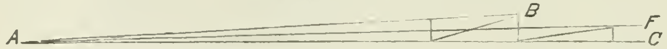
Since the total discharge of the pipe is represented by $c\sqrt{H_1}$, multiplied by a constant, the quantities discharged by similar pipes are proportional to the square roots of the heads acting on the initial orifices, or on the final orifices, or on any other orifices similarly situated. It is also apparent that in computing the discharge of the supplying main, P, the perforated pipes, a_1, a_2, a_3, etc., may be treated as orifices in the main, and the head and discharge at each represented by the above formulas, substituting proper values for b and c. It follows also that the discharge of the entire system of articulated pipes is proportional to the head at any given point in the system. It must be observed that this and the preceding paragraph apply only to pipes or systems of pipes on the same level.

Although the algebraic expression of the discharge would involve endless labor, the above formulas can be represented and extended from orifice to orifice by a geometrical construction of remarkable simplicity. Draw from A, Fig. 3 (p. 89), two lines, making an angle with each other whose tangent is $c\sqrt{b}$. Take any convenient distance, $A\ D_1$, to represent unity. Draw $D_1\ d_1$ perpendicular to $A\ C$. Make

$D_1 D_2 = A d_1$, $D_2 D_3 = D_1 d_2$, $D_3 D_4 = D_2 d_3$, etc., the several lines, $D_2 d_2$, $D_3 d_3$, etc., being perpendicular to $A C$. Then the distance, $D_1 D_2$, will represent q_2, $D_2 D_3$ will represent q_3, and $D_{n-1} D_n$ will represent q_n, leaving out of consideration the common factor $c\sqrt{H_1}$. Q_2 is also represented by $A D_2$, Q_3 by $A D_3$, Q_4 by $A D_4$. etc. Thus $A D_1 = 1$, $A d_1 = D_1 D_2 = \sqrt{1 + b c^2}$;
$D_1 d_2 = D_2 D_3 = \sqrt{\overline{D_1 D_2}^2 + b c^2 (1 + \sqrt{1 + b c^2})^2}$, etc. Any value of Q is obtained from the preceding value, by adding the square root of the sum of two terms, of which the first is the square of the immediately preceding term, and the second is $b c^2$ times the square of the sum of all the preceding terms. For instance:
$D_7 D_8 = D_6 d_7 = \sqrt{\overline{D_6 D_7}^2 + \overline{D_7 d_7}^2} = \sqrt{\overline{D_6 D_7}^2 + b c^2 \times \overline{A D_7}^2}$. Also $\left(\frac{D_6 D_7}{C}\right)^2$ represents the head acting on the seventh orifice, and $\left(\frac{D_7 d_7}{C}\right)^2$ represents the loss of head between the sixth and seventh orifices. All on the same scale on which $A D_1$ represents the discharge from the final orifice.

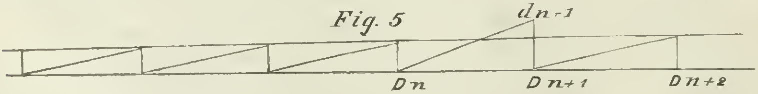
When a point is reached at which a change of diameter occurs, a new line, $A F$, Fig. 4, is drawn, corresponding to the new value of b,

Fig. 4



and the work proceeds as before, except that it is governed by the line $A F$ instead of $A B$. Usually, at a change of diameter as well as at angles, bends and couplings, a loss of head occurs in addition to that represented by $b Q^2$. Such losses are always proportional to Q^2, and may be represented by $b_1 Q^2$. At the orifice following the contraction, angle, coupling, etc., the vertical line extends above the inclined line, as in Fig. 5, being equal to $c\sqrt{b + b_1} \cdot Q_n$, and the

Fig. 5



distance $D_n d_{n+1}$ is laid off from D_{n+1} to D_{n+2}.

Having followed a perforated pipe from the final orifice to the origin, we have its total discharge and the discharge of each orifice represented by lines. We have not yet found the absolute value of any quantity, but only their relative values. The same method is applied to the main supplying the several lines of perforated pipe. Here $A\,D_1$, $D_1\,D_2$, $D_2\,D_3$, etc., Fig. 3, represent the discharge of the successive lines of perforated pipe. We come, finally, to a point in the system where the head is known or may be assumed. Here we find the line representing the discharge of an orifice. We can also compute the same from the known or assumed head. This fixes the relation between lines and quantities of water.

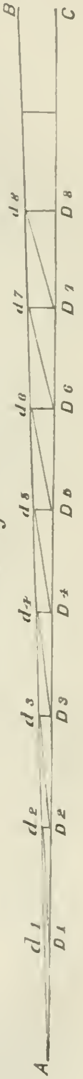


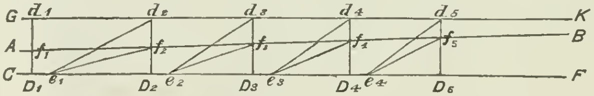
Fig. 3

Fig. 2 shows a common arrangement of sprinkler pipes, the water entering the main, *P*, at *I*, and passing in both directions. Taking $\frac{1}{2}$ inch to represent the discharge of the final orifice of a_1 and working toward *I*, we shall find the discharge of a similar orifice at *I* represented by a line which we will call x. We will, for the present, leave out of consideration the irregular pipe b_1, and consider b_2 as the last pipe on that side. Taking $\frac{1}{2}$ inch to represent the discharge of the final orifice of b_2, and working toward *I*, we shall find the discharge of the above mentioned orifice represented by a line different from x, which we will call x_1. We shall also have a line representing the total quantity going from *I* toward b_1. We must multiply this latter by $\frac{x}{x_1}$, before adding it to the line representing the total quantity going from *I* toward a_1. The sum represents the total discharge of the system by a line of which each half inch represents the discharge of the final orifice of a_1.

Perforated pipes sometimes terminate as at *A*, *B*, *C*, Fig. 2. The method here is similar to that given above. Taking $\frac{1}{2}$ inch to represent the discharge at *B*, and the same at *A*, and working from both points towards *C*, we shall have the discharge of an orifice at *C* represented, in the first case, by a line x, and, in the second, by a longer line x_1. This simply indicates that if half an inch represent the discharge of an orifice at *B*, that of an orifice at *A* should have been represented by a shorter line a. The length a should be such as to make the discharge of an orifice at C the same as is found by taking $\frac{1}{2}$ inch for the discharge of an orifice at B, whence $a : \frac{1}{2}$ inch $= x : x_1$, or $a = \frac{x}{x_1}$ times $\frac{1}{2}$ inch. The line denoting the discharge of each orifice between A and C, must be reduced in the same proportion; hence, we multiply the sum of these lines by $\frac{x}{x_1}$. We now proceed to determine the discharge of b_1, on a scale in which $\frac{1}{2}$ inch represents the discharge of an orifice at B. Arriving at the origin of b_2, by the way of b_1 and b_2, we are in a position to reduce our result to a scale in which $\frac{1}{2}$ inch represents the discharge of the final orifice of b_2. We use this scale till we reach I, when the final reduction is made, as above.[i]

The preceding refers to horizontal pipes. A special construction is required for a pipe laid at an inclination, as is necessary in the upper rooms, immediately below the roof. In this case we can only determine the discharge for some known or assumed value of the head acting on the final orifice. The loss or gain of head between two consecutive orifices, consequent on the slope of the pipe, is a known quantity, and the line which represents it must have the proper relation to that which represents the discharge from the final orifice. Such pipes, however, only occur at the top of the mill, which is precisely the point where the head is known or may be assumed.

Fig. 6



Let h_s be the difference of level between two consecutive orifices.

Let h_v be the loss of head due to velocity between two consecutive orifices.

Draw the lines $A\ B$, $C\ F$, Fig. 6, as in the case of level pipes, and draw $G\ K$ parallel to $C\ F$, at a distance therefrom $= c\sqrt{h_s}$. Then, for the case in which h_s is negative, *i. e.*, in which the water descends in moving through the pipe, let $D_1\ D_2$, Fig. 6, represent the discharge from any orifice. Draw the verticals, $D_1\,d_1$, $D_2\,d_2$; take $D_1\,D_2$ as a radius, and d_2 as a centre, and touch $C\,F$ at e_1, $e_1 f_2$ will be the discharge of the next orifice; lay this off from D_2 to D_3, and proceed as before. For, let $H_2 =$ the head acting on the orifice at D_2, then $q_2 = c\sqrt{H_2} = D_1\,D_2$. $D_2 f_2 = c\sqrt{h_v}$, and $D_2\,d_2 = c\sqrt{h_s}$,

---

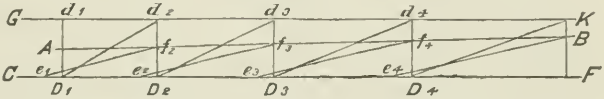
[i] The method of reduction described is simply an application of the principle that the discharge is proportional to the square root of the head.

$$e_1 f_2 = \sqrt{\overline{e_1 D_2}^2 + \overline{D_2 f_2}^2} = \sqrt{\overline{e_1 d_2}^2 - \overline{d_2 D_2}^2 + \overline{D_2 f_1}^2} = \sqrt{c^2 H_2 - c^2 h_s + c^2 h_v}$$

$$= c\sqrt{H_2 - h_s + h_v} = c\sqrt{H_3}.$$

For the case in which h_s is positive, viz., when the water ascends in moving through the pipe, let $D_1\,D_2$, Fig. 7, represent q_2, the discharge from the orifice D_2. Draw the verticals $D_1\,d_1$, $D_2\,d_2$. With D_2 as centre, and $D_2\,d_1 = D_1\,d_2$ as radius, fix the point e_1 on the line $C\,F$. $e_1\,f_2$ is the discharge of the ensuing orifice. Lay this off from D_2 to D_3. Draw the vertical $D_3\,d_3$, and proceed as before. For

Fig. 7



$$e_1 f_2 = \sqrt{\overline{e_1 D_2}^2 + \overline{D_2 f_2}^2} = \sqrt{\overline{D_1 D_2}^2 + \overline{D_2 d_2}^2 + \overline{D_2 f_2}^2} + c\sqrt{H_2 + h_s + h_v} = c\sqrt{H_3}$$

If we deduce the general algebraic expressions for H and Q, as in the case of level pipes, they will have the form:

$$H\,n = H_1\left[1 + b\,c^2 \pm (n-1)\frac{h_s}{H_1} + b\,c^2\left(1 + \sqrt{1 + b\,c^2 \pm \frac{h_s}{H_1}}\right)^2 +, \text{ etc.}\right].$$

$$Q_n = c\sqrt{H_1}$$

$$\left\{\begin{array}{l} 1 + \sqrt{1 + bc^2 \pm \frac{h_s}{H_1}} + \sqrt{1 + bc^2 \pm 2\frac{h_s}{H_1} + b\,c^2\left(1 + \sqrt{1 + bc^2 \pm \frac{h_s}{H_1}}\right)^2} + \text{etc.} \\ + \sqrt{1 + b\,c^2 \pm (n-1)\frac{h_s}{H_1} + \text{ etc.}} \end{array}\right.$$

These forms disclose a difficulty in inclined pipes not met with in level pipes, to wit:—Since the coefficient of H_1, in the expression for H, is not constant, a change of head at any orifice does not imply a proportional change at any other orifice, and, for the same reason, the total discharge is not proportional to the square root of the head at any orifice. An approximate method of determining the increase of discharge consequent upon an increase of head, in a series of similar pipes, is, to compare the orifice giving the average discharge, in the pipe remotest from the source of supply, for which the graphical computations have been made, with corresponding orifices in other pipes.

The object of the sprinklers being to arrest a fire at its commencement, the necessity for putting them in operation throughout the entire mill at the same time, would hardly ever arise. Nevertheless, as the apparatus is necessarily confided to the care of a watchman on whose discretion little reliance can be placed, the simultaneous operation of the entire system must be contemplated. The difficulty which arises here, when the size and distribution of the orifices are uniform throughout the mill is this:—Some parts of the lowest room are liable to receive three or four times as much water per square foot of area as some parts of the upper room.[1] If there is a sufficiency in the latter case, there is great excess in the former. This would be of no consequence were it not that so great a draught may diminish the head in the pipe leading from the reservoir so as to exclude the water wholly from the upper room. Were it possible to furnish a uniform supply to all parts of the mill, it would be easier to avoid this difficulty. It seems essential to the completeness of this paper to indicate a method of spacing the orifices and arranging the pipes so as to secure this end. This will only be attempted upon the supposition of level pipes though undoubtedly possible for inclined pipes.

Commencing with the final orifice, let the distance from orifice to orifice be denoted by l_1, l_2, l_3, l_4, etc. The value of b will be different for each orifice, viz., $b_1 = b$, $b_2 = b_1 \frac{l_2}{l_1}$, $b_3 = b_1 \frac{l_3}{l_1}$, etc. Then the condition that the discharge of an orifice, divided by its distance from the succeeding orifice, shall be constant, gives

---

[1] The inequality is often much greater than this. In a mill provided with sprinklers, at Lowell, to which this method was applied, it was found that some parts of the same room would receive fourteen times as much water per square foot of floor as others, the heads differing nearly in the ratio of 1 to 200. It is easy to conceive that such an arrangement might defeat its own purpose, furnishing no effective supply of water to the point where the fire exists. It must be borne in mind that it is only by calculation that the working of a system of sprinkler pipes can be ascertained, an experimental test being out of the question.

$\frac{q_1}{l_1}=\frac{q_2}{l_2}=\frac{q_3}{l_3}$, etc., whence $\frac{l_2}{l_1}=\frac{q_2}{q_1}=\sqrt{1+bc^2}$, and $l_2=l_1\sqrt{1+bc^2}$;

also

$$q_3=\frac{l_3}{l_1}q_1=\sqrt{q_2^2+b_2c^2(q_1+q_2)^2}=\sqrt{\left(\frac{l_2}{l_1}\right)^2 q_1^2+b\frac{l_2}{l_1}c^2\left(q_1+q_1\frac{l_2}{l_1}\right)^2};$$

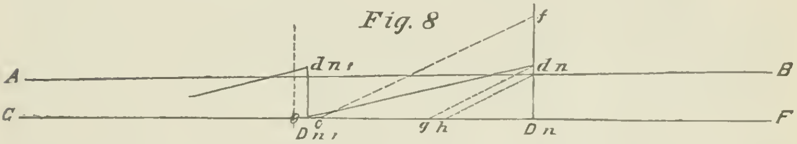
whence $\frac{l_3}{l_1}=\sqrt{\left(\frac{l_2}{l_1}\right)^2+b\,c^2\frac{l_2}{l_1}\left(1+\frac{l_2}{l_1}\right)^2}$ and $l_3=\sqrt{l_2^2+b\,c^2\frac{l_2}{l_1}(l_1+l_2)^2}$.

In like manner we find $l_4=\sqrt{l_3^2+b\,c^2\frac{l_3}{l_1}(l_1+l_2+l_3)^2}$, and

$$l_n=\sqrt{l^2_{n-1}+b\,c^2\frac{l_{n-1}}{l_1}(l_1+l_2+l_3+\text{etc.},+l_{n-1})^2}.$$

The successive values of l may be found by geometrical construction, in the following manner: The lines $A\,B$, $C\,F$, Fig. 8. being supposed to make an angle with each other whose tangent is $c\sqrt{b}$, let $D_{n-1}\,D_n$ be any two consecutive orifices, l_{n-1} being the distance between them. Lay off $D_{n-1}\,e$, $D_{n-1}\,c$, each equal to $\frac{1}{4b_1}$. With $e\,D_n$ as radius, and c as centre, touch the prolongation of $D_n\,d_n$ at f. From D_n lay off, $D_n g=D_n f$ and $D_n h=$ unity. Draw $g\,k$ parallel to $h\,d_n$. Then will $D_{n-1}\,K=l_n$. For imagine a parabola defined by the equation $y^2=\frac{l}{l_1}=2\,\frac{1}{2l_1}\,l$. D_{n-1} being the vertex of the curve, and CF its axis, c is the focus, and e is on the directrix, since both these points are at a distance from the vertex equal to half the parameter. f is a point in the curve, being equidistant from the focus and directrix, and $f\,D_n=\sqrt{\frac{l_{n-1}}{l_1}}$ $D_n\,k=D_n\,d_n\sqrt{\frac{l_{n-1}}{l_1}}=c\sqrt{b}$ times the sum

Fig. 8



of all the preceding values of l multiplied by $\sqrt{\frac{l_{n-1}}{l_1}}$, and

$$D_{n-1}\cdot k = \sqrt{l^2_{n-1} + b\,c^2 \frac{l_{n-1}}{l_1} (l_1 + l_2 + l_3 +, \text{etc.}, + l_{n-1})^2} = l_n.$$

As the head is different for every different pipe, l_1 should be proportional to the head acting on the pipe at the origin, final orifice, or any other point chosen for comparison. If the spacing is made the same in every room, the desired result may be secured by adopting a different size of orifice for each room, the area of the orifice being inversely proportional to the square root of the head acting upon the room system at the point chosen for comparison.

If both the size and distribution of the orifices are identical for every room, uniformity in the supply may be attained by diminishing the size of the pipes supplying the lower rooms or by introducing angles or contractions therein so as to occasion a loss of head for each story in excess of that for the story above, equivalent to the difference of height.

It must be remembered that the figures illustrating the geometrical construction are drawn on a very distorted scale. The angle defined by $c\sqrt{b}$, as tangent, is exceedingly small, and, in constructing the values of q, commencing with the final orifice, they will usually have to be laid off equal for several orifices, till the interval between the lines is appreciable. Likewise the value of l, starting from the final orifice, will be equal till there is a sensible interval between the lines, and for a number of orifices beyond, they will be found in the same way as that of q, till the interval between the lines is sufficient to give a sensible effect to the subsidiary construction.

For such exceedingly delicate measurements, sheet lead has been found better than paper to draw upon.

Vibrations of Matter and Æther.—M. Faye regards the emission and the absorption of radiant heat by a gas, as correlative proportions. In emission, molecular vibrations generate æthereal waves; in absorption, the æthereal waves increase the amplitude of the synchronous molecular vibrations; in each case there is an exchange of living forms between the matter and æther.—*Comptes Rendus.* C.

A NEW METHOD OF REDUCTION FOR DIFFRACTION SPECTRA OBSERVATIONS.

By Emil Rosenberg, M. D., New York.

The apparatus employed is one of those ordinary two-tube spectroscopes, provided with a simple photograph scale placed in the eyepiece of the observing telescope, and presenting divisions from 0 to 160 (actually from 10 to 160.) Though allowing only approximate determinations. such a scale is found, in certain respects, to answer our purpose better than other descriptions of measuring apparatus.

The necessity of communicating spectrum observations by referring them to wavelengths, instead of to an arbitrary scale, has long been established. The arbitrary, individual scale of a prismatic spectrum is easily converted into the rational scale of the Normal Spectrum by various methods. Though these do not here concern us, we may call the attention of observers to a table, computed by Professor Vierordt ("Die quantitative Spectralanalyse, Tübingen," 1876, page 104), which we have found very useful for this purpose.

The diffraction-grating gives the desired wavelengths directly by the well known proceeding, which ought certainly not to be replaced by a less exact method. Setting aside, however, the circumstance that not every spectroscopist is provided with the necessary measuring apparatus, there are other obvious reasons for the employment of convenient reduction-methods. Spectroscopical work is not confined to occasional investigations of the discoverer, who will prefer direct measurement, but the accumulated facts and results find eager students intent upon their acquisition. The study of established facts requires occasionally other methods than the original investigator was obliged to employ. Even the latter will, in time-consuming examinations, avail himself of reduction methods, if they permit exact determination. Moreover, the author believes that certain features of the method offered in this paper will even be profitably employed in combination with direct measurement.

The essential point for a convenient reduction-method is, to use a position of the grating, which should yield a simple and—for all regions of the spectrum—*equal* ratio of distances of the Fraunhofer lines in reference to a standard scale.

As such we adopt Angström's tenth-metre scale.

Searching for such a simple ratio with Mr. L. M. Rutherfurd's transparent 6481-line grating (which may be called R$_a$), the author found for the position of minimum deviation,

All distances of Spectrum I at the ratio 1: 20 of Angström's,
" " " II " 2:20 "
" " " III " 3:20 " etc.

Starting from this *observation*, the following relations were established for a series of diffraction-gratings:

TABLE I.

Designation of Grating.		Number of intervals per English inch.	Multiples of		Relation of Distances (at min. dev. position) to tenth-metre scale, for Spectrum.					
			540	2160	I.	II.	III.	IV.	V.	VI.
Nobert's Gratings, employed by Angström.	A$_{iii}$	2160	4	1	$\frac{1}{60}$	$\frac{1}{30}$	$\frac{1}{20}$	$\frac{1}{15}$	$\frac{1}{12}$	$\frac{1}{10}$
	A$_v$	2700	5	$1\frac{1}{4}$	$\frac{1}{48}$	$\frac{1}{24}$	$\frac{1}{16}$	$\frac{1}{12}$	$\frac{5}{48}$	$\frac{1}{8}$
	A$_{ii}$	3240	6	$1\frac{1}{2}$	$\frac{1}{40}$	$\frac{1}{20}$	$\frac{3}{40}$	$\frac{1}{10}$	$\frac{1}{8}$	$\frac{3}{20}$
	A$_{iv}$	4320	8	2	$\frac{1}{30}$	$\frac{1}{15}$	$\frac{1}{10}$	$\frac{2}{15}$	$\frac{1}{6}$	$\frac{1}{5}$
	A$_i$	5400	10	$2\frac{1}{2}$	$\frac{1}{24}$	$\frac{1}{12}$	$\frac{1}{8}$	$\frac{1}{6}$	$\frac{5}{24}$	$\frac{1}{4}$
Rutherfurd's Gratings.	R$_a$	6480	12	3	$\frac{1}{20}$	$\frac{1}{10}$	$\frac{3}{20}$	$\frac{1}{5}$	$\frac{1}{4}$	$\frac{3}{10}$
	R$_b$	8640	16	4	$\frac{1}{15}$	$\frac{2}{15}$	$\frac{1}{5}$	$\frac{4}{15}$	$\frac{1}{3}$	$\frac{2}{5}$
	R$_c$	17280	32	8	$\frac{2}{15}$	$\frac{4}{15}$	$\frac{2}{5}$	$\frac{8}{15}$	$\frac{2}{3}$	$\frac{4}{5}$

A grating of 129,600 intervals per inch would, theoretically, answer the tenth-metre scale, though actually no spectrum could be obtained from such a plate. This number may, however, be employed for finding the relation of any grating to Angström's scale. Thus, f. i., 8100 intervals per inch would present the ratio $\frac{1}{16}$ for Sp. I; a grating with a ratio of $\frac{1}{10}$ A for Sp. I, must have 12,960 intervals per inch.

The coefficients, given in Table I, have been verified for Sp. I and II of the following gratings:

A$_v$ (a photograph),
A$_{iv}$ (ruled on glass, by Mr. Rutherfurd),
R$_a$ (a photograph),
R$_b$ }
R$_c$ } (ruled on speculum metal).

These coefficients will serve various purposes:

1. For finding the correct position of minimum deviation of any grating belonging to the series, through the distances of the Fraunhofer lines, for Sp. I.

2. For determining rational scale-numbers directly from known wavelengths.

3. For determining wavelengths from observed scale-numbers.

4. For finding the number of intervals or lines of a grating, etc.

The reduction-method, based upon this definite relation, will recommend itself by its simplicity.

The grating being placed, in the usual way, at the presumptive position of minimum deviation, the latter is approximately corrected (by means of the photograph scale) by equalizing the ratio of distances of the Fraunhofer or metal lines, in reference to A's distance, according to the coefficient for Sp. I.

Thus, R_a would be adjusted to such a position, that, f. i.,

A's distance $C - D'' = 667$ $^{\text{tenth metre}}$ would be reduced to 33 $^{\text{div.}}$, 3,
$D'' - E = 626$ " " " 31 $^{\text{div.}}$, 3,
$E - b' = 86$ " " " 4 $^{\text{div.}}$, 3,
$\text{Li}\,\alpha - \text{Na} = 813$ " " " 40 $^{\text{div.}}$, 6,
$\text{Na} - \text{Th} = 543$ " " " 27 $^{\text{div.}}$, 1, etc.

A *continuous*, rational scale is then formed, the *scale-numbers* being obtained directly from the known wavelengths, by multiplying λ by the respective coefficient, in this instance, by $\frac{1}{20}$.

The *wavelength* is found from the observed scale-number, by multiplying the latter by the *inverted* coefficient, in this instance, by 20.

For R_e I, the scale-numbers are found by multiplying λ by $\frac{2}{15}$; the wavelength, by multiplying the observed scale-number by $\frac{15}{2}$.

It is scarcely necessary to remark, that for determination of *unknown* wavelengths, a more delicate measuring apparatus (micrometer screw or similar means[1]) will have to replace the photograph scale, after this has done its work.

Simple, as this method is, it was reached only after and through another more complicated one, which must be mentioned, though not recommended for practical application.

This latter method gives a *discontinuous* scale, each spectrum being observed in five separate strips, each being destined for a certain number of rays (999 tenth-metre actually fitting the scale from 0 to 160).

---

[1] Prof. Rood's micrometer eye-piece, (*Silliman's Journal*, 1873.)

The first strip for rays of 3000 to 3999 $^{\text{tenth metre}}$,
" second " " 4000 to 4999 "
" third " " 5000 to 5999 "
" fourth " " 6000 to 6999 "
" fifth " " 7000 to 7604 "

These strips are numbered respectively 3, 4, 5, 6 and 7. An incidental feature of this method is the separation of λ in two parts, viz.:

1. The first figure.

2. The balance, which is designated "l." Thus, of λ 6705, 4, we call "l" the number 705, 4. The rational scale-number is here found from the known wavelength by multiplying l by the proper coefficient, and placing the number found in the strip indicated by the first figure of the wavelength.

Spectrum *I* of R_a, arranged in 5 parts would accordingly read as follows:

STRIP-NUMBER. *a* *A*
7...9·18 30·2

α *C* *Li α* *B*
6.................................13·835 28·105 35·27 43·355

b_1 *E* *Th* *D*
5.............................9·155 13·456 17·458 44·656

h *G* *Sr δ* *F*
4..........................5·06 15·362 30·38 43·037

R *Q* *P* *O* *N* *M* *L* H_1 *H*
3....8·8 14·3 18 22 29 36·45 40·95 46·65 48·405

The wavelength is here found, by multiplying the observed scale-number by the *inverted* coefficient. The product is "l," to which the strip-number has to be prefixed as 1st figure.

A scale-number would, by this method, be incomplete without adding the strip-number in brackets; *e. g.*, 35, 27 (R_a *I*, 6) = scale-number for *L i α*.

We now return to the simple method:

By an observation made upon the two gratings, A_{iv} and A_v, the length of the first dark space, for any grating of the series, was directly determined. With these two gratings, the dispersion—in the minimum deviation position—is very small, showing the Normal simultaneously with H_1 and several other Fraunhofer lines.

The scale-numbers for H_1—as calculated from λH_1—were found by observation to correspond with the distance from the Normal in actual divisions of the scale.

The same holds good for Angström's wavelengths, which represent distances from an ideal Normal in divisions of *his* scale, in tenth-metres.

Direct observation showed the length of the first dark space for A_{iv}, to be about 100 div., for A_v about 63 div.

The scale-number: H_i for A_{iv} was observed at about 131, for A_v at about 82 (calculated respectively 131, 1 and 81, 9.)

From comparing the distance H_1—Normal (A_{iv} I) with the corresponding scale-number H_1 in the five strip arrangement: 31, 1—the first dark space was concluded to measure here exactly 100 div., the interval between 100 and 131, 1 being evidently filled by the ultraviolet spectrum.

In the same way the first dark space for A_v I was determined as measuring 62·5 div.

By means of the "reference numbers," the corresponding relations for the entire series[1] were then easily found, as detailed in Table II.

TABLE II.

Grating.	Intervals per inch.	Reference-Number (Compare Table I).	Length of first dark space, the normal being placed at 0 div.	Scale number for H_1 (I). (Continuous scale.)
A_{iii}	2160	4 or 1	50 div.	65·55 div.
A_v	2700	5 or 1¼	62·5 "	81·93 "
A_{ii}	3240	6 or 1½	75 "	98·32 "
A_{iv}	4320	8 or 2	100 "	131·1 "
A_i	5400	10 or 2½	125 "	163·87 "
R_a	6480	12 or 3	150 "	196·65 "
R_b	8640	16 or 4	200 "	262·2 "
R_c	17280	32 or 8	400 "	524·4 "

The dark space of Angström's spectrum would measure 3000 div. of his scale, 933 div. belonging to his ultraviolet.

There is another result of this reduction-method, which the author wishes to submit to the indulgent reader.

---

[1] Only those gratings of the "series," which actually exist, are specified in this paper.

By comparing our scale-number for

D (M), R_a I
$294^{\mathrm{div.}}$, 60625,

with its directly measured angle of deviation from the Normal,

8° 39′ = 519′,

one division of our scale was found to be equivalent to 1′, 762.

This holds good for any grating of the series, and for any order of spectrum.

We were thus enabled to compute in the easiest manner the "angles" for all the principal Fraunhofer lines for a number of gratings.

By employing the above-mentioned number, the angle for the D line (R_a I) was computed as 8° 39′ 5″, 7.

The measured angle 8° 39′ being certainly correct, as far as the division of the circle allowed, we might be satisfied with this base for our computations.

We believe, however, to have found a reason for changing the equivalent 1′, 762 for 1′, 8, which would make the specified angle

8° 50′ 17″, 4.

We may be permitted to state the considerations upon which our reasoning is based.

The angles corresponding to Angström's wavelengths may be calculated in the same way, as indicated above for the spectra of actually existing gratings. We find it, in fact, convenient to calculate these phantom angles from the wavelengths, and to reduce them according to the coefficients for the various gratings.

Employing for this purpose the number 1, 762, we find the angle corresponding to wavelength

1000 = 29° 22′, while by employing 1, 8 = 30°,
2000 = 58° 44′, " " " = 60°,
3000 = 88° 06′, " " " = 90°,
4000 = 117° 28′, " " " = 120°,
5000 = 146° 50′, " " " = 150°,
6000 = 176° 12′, " " " = 180°,
7000 = 205° 34′, " " " = 210°.

It is this striking regularity and harmony which leads us, at least, to doubt the correctness of the usual measurements. Instrumental means for investigating and deciding this matter are not at our disposal.

MEMOIRS ON THE LIQUEFACTION OF OXYGEN, THE LIQUEFACTION AND SOLIDIFICATION OF HYDROGEN, AND ON THE THEORIES OF THE CHANGES IN CONDITION OF BODIES.

By R. Pictet.

Translated for the Journal of the Franklin Institute, by P. Pistor, M. E.

[Continued from Vol. lxxvi, page 26.]

III.—Record of the Experiments.

Before making any definite experiments, as complex as those about to follow, each apparatus should be separately examined and its action corrected; thus we pass from the simple to the intricate. These preliminaries belong entirely to the domain of practice; equations, theories, have no bearing on them.

It is necessary to have the joints absolutely tight; the valves to close hermetically; as little friction as possible; good packing; very exact, corrected manometers; accurate thermometers; absolutely pure chemicals. There are a thousand details, too many to enumerate, each of which, however, is so important that the least oversight or inadvertency will entirely compromise final success. The slightest admission of air, so easily occurring, with four ordinary pumps working at a barometric vacuum, would be an inevitable cause of stoppage, and must be prevented at all hazards.

In generating the carbonic acid by the action of chlorhydric acid on marble, the gas must be dried, the primary substances examined, and the gasometer completely freed of air. For the oxygen, the chlorate of potassa must be absolutely pure and dry, and must be introduced, so that no foreign body can get mixed with it.

Finally, a thousand precautions must be taken, and it may be affirmed that none too many can be adopted. In this respect we owe a gratefully acknowledgment to M. le Dr. Monnier, Professor of Biological Chemistry at the University of Geneva, who has lent us his aid with great kindness, as well as to M. Walter, his assistant, and to M. Burgin, engineer, a member of our society.

The first (incomplete) experiments consisted in obtaining the low temperatures regularly, and maintaining them for several hours, so as to feel sure of this essential part of the preparations. It cost us more than fifteen days of trials and experiments to reach a satisfactory result. This is briefly what those experiments taught us.

The first condenser I made for the carbonic acid, consisted of a copper worm immersed in a recipient of the same metal, containing liquid sulphurous acid. When the temperature of the sulphurous acid went below — 65°, the carbonic acid would then solidify in the interior of the worm; the pressure would, in a few instants, reach 12 or even 14 atmospheres, as the worm being entirely full, the condensing surface would almost completely disappear.

This accident induced me to adopt the arrangement shown in Plate I.[1] The worm was replaced by a tube six centimetres, in diameter. Then solidification need not be feared if it should occur, as the available volume is more than sufficient to accommodate the whole contents of the gasometer.

During this first series of preliminary experiments, I recorded the maximum tensions of the vapors, of carbonic acid and of protoxyde of nitrogen, corresponding to the temperatures indicated by an alcoholic thermometer, constructed by the firm of Salleron, of Paris. These observations give figures which are materially different from those found in the books on physics, especially those relating to protoxyde of nitrogen. Further on I will give these figures in a table.

Once accustomed to the co-ordinated motions required to set the four pumps in operation and to regulate the cocks, I proceeded, on the morning of the 22d of December, 1877, to make a complete experiment. The following is an abstract of my notes taken during the experiment:

1st experiment of December 22.—The pumps are started at nine o'clock in the morning. The temperature rapidly falls in tube R.

9.30.—The temperature is — 55°. The carbonic acid pumps are started. The gasometer descends. The pressure of the carbonic acid is 6 atmospheres. It slowly rises during the working of the pumps to 8 atmospheres.

9.50.—The temperature is — 49°; the pressure 8·5 atmospheres. I stop the admission of carbonic acid to the pumps.

10.20.—Temperature — 65°; pressure 3·9 atmospheres.

---

[1] See preceding number of the JOURNAL.

I allow a slight admission of gas.

10.40.—Temperature —60; pressure 5 atmospheres.

800 litres of carbonic acid gas are already liquefied.

Hoar frost covers the lower part of the oxygen manometer m'.

10.50.—The flask is screwed on to tube A. It is charged with 700 grammes of chlorate of potassa, mixed with 250 grammes of chloride of potassium, bruised together in a mortar, sifted and thoroughly dried.

11.—The crown of gas under the flask is lighted.

Carbonic acid is admitted more freely into the pumps. The pressure rises to 10 atmospheres; the temperature —48°. We are sure that all the carbonic acid has passed over into the long tube *D*, as hoar frost appears on pipe c'' which connects with the upper part of tube *D*.

11.15.—Pipe c'' is connected with the suction of the pumps; the temperature of the carbonic acid reaches a minimum, —130°.

11.35.—The oxygen manometer m' records an increasing pressure of about 5 atmospheres.

The influence of the two circulations of sulphurous and carbonic acids is completely established.

12.10.—The oxygen manometer records 50 atmospheres.

12.16.—The pressure rises to 60 atmospheres, then rises gradually as follows:

12.23. . . .	Pressure	70	atmospheres.
12.29. . . .	"	80	"
12.34. . . .	"	90	"
12.36. . . .	"	100	"
12.37. . . .	"	150	"
12.37.25. . . .	"	200	"
12.38. . . .	"	460	"
12.39. . . .	"	510	"
12.39.30. . . .	"	522	"
12.40. . . .	"	525	"
12.42. . . .	"	526	"
12.44. . . .	"	525	"
12.48. . . .	"	505	"
12.50. . . .	"	495	"
1.00. . . .	"	471	"
1.05. . . .	"	471	"

The pressure is stationary, consequently all the chemical and physical phenomena have terminated.

The condensation has caused the fall of pressure recorded by the manometer, and the whole volume represented by the interior capacity of tube A, is full of liquid oxygen. There is certainly an excess of gas, which causes a higher pressure than the maximum tension due to the temperature of liquid carbonic acid.

1.10.—The pressure is exactly at 470 atmospheres; I open the screw plug which closes tube A.

A liquid jet issues with great violence, and assumes the appearance of a brilliant white pencil. A bluish halo surrounds this jet, especially its lower part. The length of the liquid pencil is about 10 or 12 centimetres and about 1·5 to 2 centimetres in diameter. The jet lasts about three or four seconds.

I close the regulating cock; the pressure is still 396 atmospheres. In a few minutes it falls to 352, where it remains stationary for about three minutes.

1.18.—I reopen the screw plug, a second liquid jet issues similar to the first one. But following it, the gas escapes of well-defined aeriform appearance. The gas in expanding creates a mist by its partial condensation; however, it is evident that it issues from the orifice in a different form from that which it previously had, there being certainly no liquid in the tube.

1.19.—The pressure is 50 atmospheres. The gas escapes, still producing a visible bluish mist, but with no evidence of liquid being carried with it.

Hot coals, placed under the second jet, blaze up in an instant with great violence, throwing sparks in all directions.

This first experiment is amply sufficient to demonstrate experimentally that oxygen can be liquefied.

The variation of the pressures is a still more positive proof, if that were possible, than the appearance of the jet at the opening. However, the perfect harmony which exists between these closely related phenomena, and the possibility of introducing all these numerical data into the calculations, induced us to repeat the same experiment several times in succession, so as to be able to determine the density of liquid oxygen as well as its maximum tension for a given temperature. These two physical elements are the most important, and characterize the general properties of the new fluid. With this object we describe five consecutive experiments which enable us to obtain accurate numerical mean values.

We measured with the greatest care the following—

1. The total weight of chlorate of potassa and of the chloride of potassium introduced into the flask.
2. The temperature at which the reaction occurred.
3. The exact volume of the chloride of potassium constituting the residue.
4. The volume occupied by the compressed oxygen.
5. The contents of the tube in which the oxygen is to be condensed.
6. The theoretical pressure which should be reached in case there were no condensation.
7. The pressure reached at the moment the chlorate of potassa is decomposed.
8. The static pressure after condensation.
9. The variation of the manometer after the first jet, when a second condensation commences.
10. The static pressure after condensation, when the tube is entirely filled for the second time. This pressure is characterized by the hand remaining stationary during several minutes.
11. The same after the second jet.
12. To determine, by the position of the hand, of the manometer, the maximum pressure at which condensation occurs.

This position is found when the hand recedes less than would be due to the condensation of a volume of liquid equal to the volume of the chilled tube. The permanency of this pressure is a sure and infallible sign which enables us to determine this maximum tension readily.

13. The temperature of the solid carbonic acid enveloping tube A.
14. The density of the gaseous oxygen.

These different numerical data enable us to compute the "density of liquid oxygen" with sufficient exactitude, as we will prove later. As it is useless to encumber this pamphlet with figures, we will relate but one of the five experiments made, December 27th, at 8.10 P. M. The others, conducted in a similar manner, only differ in the recorded duration of the jets and in a few differences in pressure, which we will specify in the tables.

Experiments of December 27th, at 8.10 P. M.—The ice-pumps are started at about eight o'clock, and the carbonic acid pumps soon after.

At 9.30 the hoar frost appears on the return tube c″, showing that the large tube *D* is completely filled with solid carbonic acid. Our metallic manometer, showing an error of 29 atmospheres at the start, we give below the pressures corrected for this error of the dial. An error of no importance, however, as regards the absolute value of the observations.

8.32	P. M.	Pressure	50	atmospheres.
8.38.20	"	"	60	"
8.45	"	"	70	"
8.50.10	"	"	80	"
8.51.40	"	"	90	"
8.52	"	"	100	"
8.52.15	"	"	155	"
8.52.30	"	"	220	"
8.52.45	"	"	310	"
8.52.55	"	"	390	"
8.53	"	"	490	"
8.53.15	"	"	520	"
8.53.30	"	"	525	"
8.53.45	"	"	526	"
8.54	"	"	525	"
8.55	"	"	523	"
8.57	"	"	500	"
8.59	"	"	489	"
9.00	"	"	480	"
9.5	"	"	475	"
9.10	"	"	472	"
9.15	"	"	471	"
9.17	"	"	471	"

The pressure having become stationary, I open the plug-cock ; a jet of liquid escapes, illuminated by a halo of electric light. The previously described appearance can be clearly observed. At the moment of closing, the pressure is exactly 432 atmospheres.

9.17.15	P. M.	Pressure	432	atmospheres.
9.18	"	"	429	"
9·19	"	"	422	"
9.20	"	"	412	"
9.21	"	"	405	"
9.22	"	"	395	"
9.23	"	"	390	"
9.24	"	"	386	"
9.25	"	"	383	"

9.26	P. M.	Pressure	380	atmospheres.
9.27	"	"	379	"
9.28	"	"	378	"
9.29	"	"	378	"
9.30	"	"	378	"
9.31	"	"	378	"
9.32	"	"	378	"
9.35	"	"	378	"

The pressure has become stationary a second time, the manometer has recorded steadily falling pressures, from 432 to 378 atmospheres, where it again remains stationary. Difference 54 atmospheres.

I open the plug-cock; a jet escapes similar to the first, and of the same duration. As soon as traces of gas manifest themselves at the orifice, I conclude that all the liquid has escaped, and close the cock instantly.

9.35.15	P. M.	Pressure	291	atmospheres.
9.36	"	"	285	"
9.37	"	"	280	"
9.38	"	"	276	"
9.39	"	"	272	"
9.40	"	"	"	"
9.41	"	"	"	"
9.42	"	"	"	"
9.43	"	"	"	"
9.44	"	"	"	"
9.45	"	"	"	"
9.46	"	"	"	"
9.50	"	"	"	"

A third time the pressure is stationary, only it has fallen but 19 atmospheres in 15 minutes. Previously it fell 54 atmospheres during the same time. I open the cock; a small quantity of liquid escapes, but almost immediately gas alone. The change is so apparent that it was noticed by more than twenty spectators at the same moment.

The mist produced by the expansion of the gas is very perceptible, but the general appearance of the jet is entirely modified, and no one would mistake these two successive phases.

From this moment the manometer remains stationary when the cock is shut. It remains so after every closing.

9 52 P. M.	Pressure	225	atmospheres.
9.53 “	“	225	“
New jet of gas—			
9.54 P. M.	Pressure	190	“
9.55 “	“	190	“
Gaseous jet—			
9.56 P. M.	Pressure	143	“
9.57 “	“	143	“
Longer gaseous jet—			
9.54 P. M.	Pressure	72	“
9.55 “	“	72	“
Last gaseous jet—			
9.56 P. M.	Pressure	0	“

The experiment is finished. The flask is removed while still hot, so as to prevent the plug from binding. The mouth is closed with a cork, and it is left to cool; when cold water is poured into the interior, until its level reaches the copper joint to which the screw-plug was attached. This water evidently occupies the same volume filled by the oxygen during the experiment.

The weight of the water poured into the flask is known accurately by twice weighing the receptacle in which it was. Weigh it before filling and after—the difference corresponds to the weight of water poured off. This weight was exactly 944 grammes; the volume is consequently 944 cubic centimetres.

Another observation also recorded during the experiment was the pressure, P, corresponding to the vacuum formed by the carbonic acid pumps, so as to determine the temperature at which liquefaction takes place. These observations were repeated several times, and the results agree so completely for all the experiments, that the averages are absolutely exact.

We will here particularize a minor point, which, however, is of importance for the determination of the temperature of the flask during the operation.

So as to avoid all danger of explosion, should an unforseen accident occur, I surrounded the flask with three large cast-iron rings placed one on the other. They form a sort of thick sheathing, 50 centimetres in height, of 23 cm. interior diameter, and 32·5 cm. exterior diameter.

There is a clear annular space of about 3 cm. between the flask, which is in the centre, and the inside of this sheathing, and through which the gas flames can circulate.

This arrangement allows the flask to heat very evenly; and when the temperature is high enough to cause chemical reaction, has the special advantage of retaining this heat a long time without great variation.

The external radiation cannot have any influence on the flask, only on the sheathing, whose enormous mass represents a sufficient quantity of heat stored up.

We have searched all the most reliable authorities for the necessary data to determine this very high temperature.

Judging from the softening of glass; from the temperatures which produce a dull red color; from the fusion of metals; from the use of an air thermometer; it can be assumed that this temperature is between 480° and 500°; a temperature of 525° would be a maximum, and 480° would be too low.

The gas flame having been extinguished since the reaction was finished, the temperature remains about stationary during the following half-hour. We will assume it at 485° in our calculations; basing this assumption on the fact that our experiments have lasted sufficiently long to give to this lower figure a greater degree of exactitude than to the higher one. In this respect an error of 20 degrees is admissible, and has but a slight influence on the numerical result.

Of the five experiments made to liquefy oxygen, three were made with carbonic acid and two with protoxyde of nitrogen.

These experiments took place:

1st. Monday, Dec. 24, from 9 A. M. to 1 P. M., with carbonic acid.

2d. Thursday, Dec. 27, from 10 A. M. to 12, with carbonic acid.

3d. Thursday, Dec. 27, from 8 A. M. to 10 P. M., with carbonic acid.

4th. Saturday, Dec. 29, from 4 to 6 P. M., protox. nitrogen.

5th. Friday, Jan. 4, from 4 to 6 P. M., protox. nitrogen.

As already stated, we do not intend giving all the data, *in extenso*, to hours and minutes, relating to these experiments, but will group in the following table the essential results which characterize the phenomena of liquefaction, and which serve as a basis for calculations.

In every experiment, we have introduced into the flask exactly the same quantity of chlorate of potassa mixed with chloride of potassium.

These chemicals, prepared with the greatest care in the chemical laboratory of Prof. Mounier, have been dried, melted, then bruised before being placed in the recipient. The quantities I used in these five experiments were:

Chlorate of potassa,	700 grammes,
Chloride of potassium,	300 "

The most important observations refer to five successive phases in each experiment. We will specify them:

1st. The maximum pressure observed on the manometer after all the gas has been liberated, and after condensation has taken place in the tube."

This pressure is stationary during one-quarter of an hour at least. It is always less than the pressure recorded by the manometer at the end of the extremely rapid chemical reaction.

2d. "The pressure after the first jet," when it is "*distinctly*" observed that the liquid jet is replaced by a gaseous one.

Close the cock and record the pressure instantly.

3d. "The stationary pressure which follows the constantly diminishing pressure during this last operation."

The condensation of oxygen in the tube causes this fall of pressure. When the tube is filled a second time, condensation is suddenly interrupted, and the pressure becomes stationary.

4th. "The pressure after the second jet."

5th. "The stationary pressure after the second jet."

In none of our experiments has the third jet been complete; it was always perceptibly shorter than the first two, which proves that condensation could not have been sufficiently abundant to fill the chilled tube three times.

We shall see in the following chapter how these numerical data can give us the density of the liquid oxygen.

Here is the table of the five experiments which we designate by numbers 1 to 5 at the head of the corresponding column.

The pressures are corrected for the error of the manometer, and represent the effective tensions.

TABLE OF THE NUMERICAL RESULTS OBTAINED DURING FIVE CONSECUTIVE EXPERIMENTS ON THE LIQUEFACTION OF OXYGEN.

NOTABLE PRESSURES.	PRESSURES GIVEN IN ATMOSPHERES.				
No. of Experiment.	1.	2.	3.	4.	5.
1. Maximum stationary pressure of oxygen before first jet issues, ...	470	471	471	469	469
2. Pressure indicated immediately after first liquid jet, . .	367	395	432	400	416
3. Stationary pressure before second liquid jet, lasting several minutes, ...	308	339	378	346	361
4. Pressure after second jet, .	285	290	291	285	296
5. Stationary pressure before third liquid jet, ...	274	271	272	251	253
6. Pressure immediately after third jet, which is of very short duration, ...	. . .	245	. . .	215	205
7. Stationary pressure reached about five minutes after third jet,	. . .	253	. . .	218	212
8. Pressure after fourth jet, which is still gaseous, ...	0	0	0	0	0

In the following chapter we will make use of the numerical results contained in this table, to calculate the density of liquid oxygen by two different methods.

(To be continued.)

THE SINGING TELEPHONE AT THE STEVENS INSTITUTE OF TECHNOLOGY.

By Henry Morton, Ph. D., President.

A number of experiments have been made at the Stevens Institute of Technology with telephones for singing and for speaking, which, while not of a nature to form a systematic research, have, nevertheless, developed facts of sufficient interest to merit some record. These experiments were chiefly conducted during the summer holidays, by several students and graduates connected with the Institute, under the general direction of the present writer, and were carried on, in the first place, mainly with the view of developing a loud-sounding instrument to transmit musical tones, and thus fitted for use in illustrating public lectures on the subject.

The gentlemen concerned in these experiments were Messrs. Wm. E. Geyer, Henry A. Beckmeyer, and Brown Ayres.

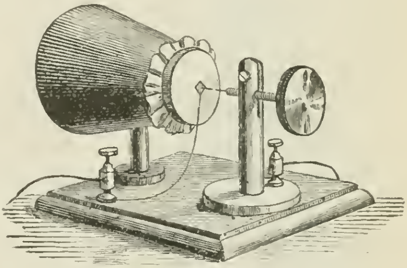
The point of departure was the oldest form of the singing telephone, described by Reiss in 1863, and consisting of a transmitting and a receiving instrument. This transmitter, used by Reiss, consisted of a mouthpiece like that of an ordinary speaking tube, connected with a box or chamber, one surface of which was provided with a large round aperture covered with a parchment diaphragm. To the centre of this diaphragm was attached a small plate of platinum, with a metallic connection, to a binding-post. Opposite this central point of the diaphragm was supported a screw, with a platinum point, adjustable so as to touch the platinum plate on the diaphragm lightly when at rest. On singing into the mouthpiece the diaphragm was made to vibrate in unison with the note, and thus a corresponding intermittent current was transmitted to the receiving instrument.

The receiving instrument employed by Reiss consisted, at first, of a simple electro-magnet mounted on a resonant case, the sounds produced being simply due to the molecular changes in the soft iron bar of said magnet. Afterwards he used an electro-magnet, with a movable armature, whose vibrations then became the source of the sound.

The transmitting instrument employed by us (shown in Fig. 1) was made in the shops of Messrs. Geo. Wale & Co., located in our building, and consisted of a truncated hollow brass cone, provided with a ring slipping over its smaller end, by means of which a diaphragm of thin sheet rubber could be readily attached. To the centre of this diaphragm was attached a small circular piece of platinum foil, to which was soldered a very fine copper wire, which led to a binding-screw upon the base-board of the instrument. Opposite the diaphragm was a screw, with platinum point, supported on a brass column, so as to touch lightly the platinum foil in the centre of the diaphragm. The base of this column was also provided with a binding-screw, to carry on the connection.

This apparatus being connected with a battery, it is evident that on singing into the cone, vibrations corresponding to the note would occur in the diaphragm, and these would, in turn, cause ruptures and renewals of contact corresponding, in frequency, between the platinum foil on the diaphragm and the point of the opposing wire.

Fig. 1.



This was, in effect, nothing more than the transmitter of Reiss, made more compact and adjustable.

After numerous experiments with other plans, which operated with greater or less success, the following arrangement was made by Mr. Geyer, with much better results than any we had obtained before. An ordinary U-shaped electro-magnet, about three inches long, wound with coarse wire, so as to have only about two ohms resistance, was supported with its limbs vertical and the ends of its poles turned upwards. On each pole was laid a narrow thread of soft india-rubber. Upon these again rested an ordinary armature cemented to the resonant case of an Æolian harp.

The intermittent current here produced vibrations by fluctuations in the attraction between the magnet and armature, the necessary resilient force being supplied by the lines of rubber on the face of the magnet. With this instrument the sound produced was loud enough to be heard over a large room.

For greater convenience, however, the magnet was supported in a horizontal position, thin rubber bands, such as are used for filing papers, being stretched on it, so as to cross the face of each pole. The armature was attached to the bridge of a guitar, which, in its turn, was hung from an upright stand, so as to have the armature rest against the poles of the magnet.

This gave to the whole apparatus an elegant appearance, and produced a very striking effect in its use, as the guitar could be hung on its support without any special care or adjustment, and would then immediately begin to sound out the tune which was being transmitted from the other end of the line.

Such an instrument was fitted up for a concert troupe, who have been traveling over the country for some months past, and has given, we hear, entire satisfaction, exhibitions having been made with it in some of the largest concert rooms and other public buildings.

In the course of some experiments which he made during the summer, Mr. Ayres found that a telephone—made after the pattern of those used by Mr. Graham Bell at his lectures in New York last spring, and consisting of a permanent magnet with soft iron pins attached to its poles, these being surrounded with coils of fine wire, and having opposite to them a disc of sheet-iron about six inches in diameter—made an unexpectedly good receiver for a current transmitted by such a Reiss transmitter as we have described.

An application of this was soon made to what we may call the "guitar receiver," see Fig. 2, by Mr. Beckmeyer, who, securing the guitar firmly in an erect position, brought a large permanent U magnet, with soft iron pins and fine wire coils, very close to the armature which was attached to the guitar.

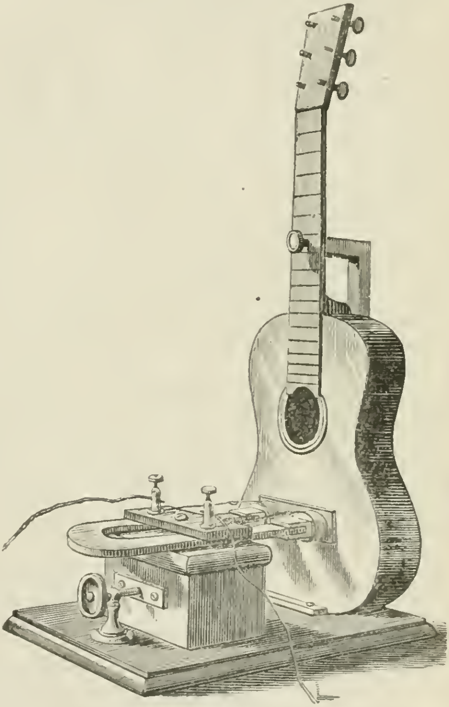
The instrument, so arranged, was found to give a louder sound, and to operate more easily than the previous one. The battery used in all these experiments consisted of six Leclanché cells of the usual kind supplied by the Leclanché Battery Company, 40 West 18th Street, N. Y.

It struck the present writer as a very remarkable circumstance, that effects so nearly alike should be obtained under such different conditions as were here present. Thus, in what may be distinguished as Mr. Geyer's telephone, the resistance of the magnet was only about 3 ohms; while in what we may call Mr. Beckmeyer's arrangement, it was about 200 ohms.

A series of experiments, carried on at his suggestion, also showed that the excellence of effect in loudness and range of tone did not depend upon the mere strength of the magnetic attraction, but might be greatest when that was least, and that the suppression of the extra current by the use of a condenser seriously impaired the effect of the apparatus.

This seemed to indicate that currents of high intensity, such as the extra current or an induced current, might be of special efficiency.

Fig. 2.



Such, indeed, proved to be the case. The battery current, interrupted by the transmitter, was passed through the primary of a small induction coil, and the secondary circuit of the same was then connected with the line in which the guitar receiver was placed.

Under these circumstances the results obtained were very excellent, the sounds produced being quite as loud as those from the battery current.

There was also another advantage in this arrangement, namely, that lines of very high resistance could be interposed, and thus the induced current could pass, for example, through the bodies of several persons and yet produce loud music in the guitar. This makes a very striking lecture illustration or experiment.

Though reached independently by the course of reasoning and experiment here noted, no claim of originality is made in this connection, for one of Mr. E. Gray's patents covers the use of an induced current with an electro-magnet and armature attached to a sounding-board.

A further practical improvement was made in the transmitter at the suggestion of Mr. Ayres, by substituting thick letter paper for the sheet-rubber diaphragm.

This greatly increased the range of action of this part of the apparatus, and thus facilitated its adjustment, and made the certainty of its action on all occasions much greater.

Another matter of practical importance was seen to be a convenient and portable battery, sufficiently constant to operate the apparatus for the time of ordinary experiments, without unnecessary bulk and weight. To meet this requirement, the present writer designed the following arrangement which was constructed for him, and is now regularly manufactured by Messrs. Geo. Wale & Co.

Ten glass specimen tubes, 1¼ by 4 inches, in other words, large test tubes, flat at the bottom and with heavy glass rings at the top, are set in holes bored in a strip of wood secured against a flat piece of thin board, 8 by 12 inches. At the upper part of this board are attached two staples of brass, into which drop the ends of a bar of wood. On the bar are fastened, by a single screw each, seven rectangular pieces of sheet brass. Each one of these, except the terminal one, holds, by simple pressure, a wire connected with an element of carbon or zinc on either side. These elements dip appropriately in the tubes. The terminal plates of brass hold only one wire each, and close the end connections by contact with the staples, each of which has a binding-screw in its lower part.

A very cheap, compact, and yet efficient, battery is thus produced. For exciting fluid, a strong solution of Glauber salt will answer very well, so will one of sal-ammoniac; both of these are entirely non-corrosive and harmless if spilled. Dilute sulphuric acid produces more energetic effects, but even the neutral solutions will produce all the force necessary to fill the largest lecture room with sound from the guitar.

A NEW METHOD OF GRINDING GLASS SPECULA.

By Prof. Elihu Thomson.

The use of glass in the construction of specula for telescopes has almost superseded that of metal. The many advantages arising from the employment of silvered glass specula are well known, many fine mirrors constructed of this material being in existence.

The principal expense to amateurs and others desiring to construct for themselves a serviceable speculum arises from the preparation of metal-grinding tools. These, usually two in number, are generally made of brass or cast-iron, carefully turned and scraped to approximate curves, and finally ground together until the desired accuracy of surface is obtained.

This operation of fitting requires the use of special appliances, and is at once a tedious and difficult operation to the unpracticed. The tools, prepared as stated, are employed to give form to the glass which is to constitute the reflector.

The obvious difficulties of preparing metal-grinding tools of large size; the impossibility of avoiding conditions of strain in cast metal, and the greater expansion by heat of the metal tool than of the glass to be worked, make it desirable to avoid the use of metal-grinders where practicable. This is particularly the case where but one or two specula of any given focal length are to be prepared.

It is believed that the method presently to be described provides a means of obtaining a good figure at the same time that the metal tools are completely dispensed with, and from the simplicity of the process any one who can give the requisite care demanded by all work of the kind, may practice it with success.

The principle of the method is, the fact that when two equal discs of glass or other material are ground together, one above the other, the under one always becomes convex while the upper one becomes concave, and, by making the strokes of the upper disc wide and sweeping, this change of form may be greatly accelerated.

The reason for this is obvious: when the upper disc *A*, Fig. 1, is in the position there shown, the downward pressure is principally upon the edge of the lower disc and upon the centre of the upper one, thereby causing a greater action of the interposed grinding material upon those parts, so that there eventually results a form similar to Fig. 2. The strokes may be so made that the surfaces in contact become spherical, this condition being greatly favored by the fact of the material of the two discs having the same relative hardness, elasticity and expansion by accidental changes of temperature during the grinding operation.

By testing, from time to time, the curve acquired by the discs, any desired radius may be obtained.

Where a spherometer is not at hand, simply using the wet concave in the sun and noticing at what distance from the centre of the disc the reflected rays give the best defined image, we are enabled to obtain the focal length at any stage of the process. Where solar light is not available, the rays of a lamp may obviously be used to obtain the data for calculating the focal length.

The details of the process are as follows: The grinding material is, of course, emery of various degrees of fineness, the polishing being accomplished with rouge or ferric oxide, prepared either by heating pure ferrous sulphate to decomposition, or by heating precipitated ferric hydrate to a bright red.

Fig. 1

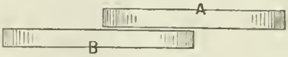
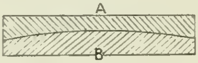


Fig. 2.



For details, as to preparation of emeries, precautions to be taken. methods of testing surfaces obtained, etc., we refer to Dr. Draper's very able paper on "Silvered Glass Specula," in the Smithsonian Contributions, Vol. XIV.

Two discs of heavy skylight glass, nearly free from bubbles and other imperfections, are obtained. They should be of a thickness not less than half an inch, for a diameter of four or five inches, and should increase in thickness with increase of diameter. The edges should be circular, rough or sharp edges being removed by grinding. The surfaces should be flat, and parallel to each other.

The disc which is to be the under one during the grinding process, and which we shall designate *B*, is placed upon a grinding-post, Fig. 3, the under surface being equally supported at its various points. The disc is kept in position by pieces of wood, *a*, *a*, *a*, *a*, Fig. 4, placed around it at regular intervals, thus permitting easy removal, if desired. The grinding-post, as is usual, may consist of a barrel, weighted or held firmly to the floor.

Having cemented a handle to the back of the disc which is to become the speculum, and which we shall designate *A*, it is placed upon the disc, *B*, emery, say, No. 60, and water supplied, and ground over *B* with wide, swinging strokes, fresh emery being supplied as needed. This process is continued until the tests of curve above mentioned show that the disc *A* has acquired a surface, the focus of which is somewhat longer, say $\frac{1}{8}$, than the desired focus. The discs are now carefully washed, to get rid of all the coarse emery, and a finer grade, say 90, applied for continuing the grinding. The same operation is repeated, using flour emery, and afterwards the washed grades, which may be, successively, $\frac{1}{2}$ min., 5 min. and 10 min. emeries. Between each grade a careful washing of the hands, discs, etc., is necessary, to avoid retention of coarse particles that may fall subsequently upon the glass surfaces, and produce scratches difficult to remove. While using the flour emery, the curve can, with proper care, be made to reach that required to produce the desired focus, on attaining which the swing of stroke is to be lessened, to avoid shortening the focus.

Fig. 3.

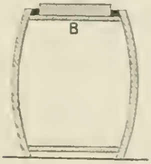


Fig 4.

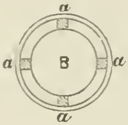
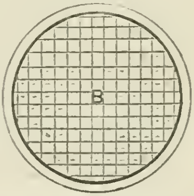


Fig. 5.



The grinding with the very fine grades of emery, seldom produces any considerable change in the focal length, if the proper stroke be given. If, through any cause, too short a focus has been obtained, it can easily be lengthened by reversing the relative positions of the two glass discs, making *A* the lower. To obtain a spherical surface, all possible directions of motion are to be given to the upper disc, and the operator should work from various sides of the grinding-post. It may here be said that the writer has not had the opportunity of applying this method to production of specula, otherwise than by hand. There is little doubt, however, of its success with appropriate machinery.

In the last and final grinding with emery, the greatest care must be exercised, as much time may be saved in the polishing by the attainment of a good surface and figure by the grinding.

In the employment of the finest grade of emery, the last charge should be kept on and worked down so smoothly that no grinding noise is made by the two surfaces sliding one over the other. Just sufficient water should be added to keep the surfaces uniformly wet, an excess being apt to wash off the fine cutting powder so essential to success in this part of the operation. The smoothing is continued until the surface of A can reflect the light of a window at incidences of 40° to 50°, and when examined by transmitted light, preferably by using a magnifier, should present *a very fine and uniform grain.* Before making any change in grade of emery, it is essential that all marks made by previous sizes have been obliterated.

If, in the fine grinding, after sufficient examination, the conditions mentioned appear to have been attained, the speculum is ready for the polishing. This is done in the usual manner. The polisher is prepared by coating the lower or convex disc, B, with a layer of pitch, or other well-known composition, to about $\frac{1}{8}$ inch thickness, and after having warmed the coated disc so as to soften the pitch, the concave disc, A, is wetted and pressed upon the pitch surface of B, to ensure a fit.

Parallel grooves are then made in the pitch surface in such a way as to divide it into squares of uniform size, Fig. 5—a well known procedure in polishing specula—after which the surfaces are again carefully fitted as stated above. Preferably, the diameter of the polisher is about one-tenth or one-eighth less than that of the surface to be polished by it, as by this means the desired figure is more readily obtained.

The disc A, to be polished, is now laid upon the grinding-post, concave side upward, and the polisher, B, charged with finely washed rouge, worked in all directions on it, occasional additions of rouge being made. When the surface of the speculum is sufficiently polished to reflect light, tests of figure are made from time to time, the methods of Draper and Foucalt being admirable for the purpose. The attainment of a spherical surface is in this way free from especial difficulties; and it may be converted subsequently into that of a paraboloid of revolution by the method recommended by Dr. Draper, and fully described in his paper previously referred to.

It cannot be too strongly urged upon those attempting the construction of specula that changes of temperature, by handling or otherwise, must, during the polishing, be carefully avoided. The silvering of the finished speculum is readily accomplished by following closely the method given by Dr. Draper.

Tests of this method of grinding specula, made during the last two years, show that its capabilities are at least equal to those of the usual process with grinding-tools of metal, and it is possible that with increased experience the latter may be surpassed. The method has, however, undoubtedly the advantage of a saving of time in preparation of the tools, as also of expense for materials used.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS, DURING THE LAST TEN YEARS.[i]

By Dr. A. W. Hofmann.

From the *Chemical News.*

[Continued from Vol. lxxv, page 415.]

R. Wagner proposes[ii] to employ in the preparation of nitric acid the hydrated alumina obtained as a by-product in the treatment of cryolite and bauxite. If this is ignited with Chili nitre, nitric and hyponitric acids escape, the latter being utilized by treatment with air and water. The residual aluminate of soda is decomposed with carbonic acid into carbonate of soda and hydrate of alumina, the latter being utilized in the decomposition of fresh quantities of nitre. Instead of the hydrated alumina, Wagner thinks it possible to use finely-divided silica, as obtained on the decomposition of soluble glass or of fluoride of silicium. The method, proposed as early as 1865 by Wagner, has subsequently been twice patented in England, in 1867 by J. Poole, W. Stase, and H. Baker,[iii] and in 1870 by J. H.

---

[i] "Berichte über die Entwickelung der Chemischen Industrie während des letzten Jahrzehends."

[ii] R. Wagner, *Wagner's Jahresber.*, 1865, 249.

[iii] *Deutsche Industrie Zeitung*, 1867, 158; *Wagner Jahresber.*, 1867, 998.

Johnson.[i] As far as known to the author, this method has not been carried out on the large scale.

Tessié du Motay[ii] proposes to pass a mixture of ammonia and oxygen over manganates, permanganates, and chromates, heated to 340° to 560°, decomposing the nitrates thus formed by air and steam at a red heat, when nitric acid is liberated, and the chromates or manganates are regenerated. Like so many other suggestions of this much-inventing chemist, the process has not come into industrial utilization.

R. Weber[iii] has recently made known a method for obtaining St.-Claire Deville's anhydrous nitric acid easily and in quantity. He adds anhydrous phosphoric acid to the refrigerated monohydrated nitric acid, and distils at a gentle heat. The distillate consists of two non-miscible liquids. The upper stratum is decanted off and cooled below 0°, when crystals of nitric anhydride are formed in abundance. According to Weber's statement, confirmed by Berthelot,[iv] the yield is very satisfactory.

A very sensitive test for nitric acid is sulphate of brucin, which gives an intense red color. On adding stannous chloride a violet precipitate is produced.

According to the statement of C. D. Braun,[v] confirmed by Böttger,[vi] sulphate of aniline is equally sensitive with the brucin salt. A solution of aniline sulphate is prepared by dissolving 10 drops of aniline in 50 c.c. of dilute sulphuric acid (1 : 6). Half a c.c. of this solution is then placed in a watch-glass, mixed with 1 c.c. of concentrated sulphuric acid, and a glass rod moistened with the liquid to be tested is drawn through the margin of the mixture. In presence of nitric acid red stripes appear, and the whole liquid gradually turns to a rose color. If more nitric acid is present the color becomes a deep red-brown, and finally a brownish yellow.

---

[i] J. H. Johnson, Specification 2866, October 31, 1870. (The process was tried experimentally in England, about 1850, at the works of Messrs. Metz and Halcrow, Droylsden, near Manchester, but was not considered remunerative.–Ed. *C. N.*)

[ii] *Deutsche Industrie Zeitung*, 1871, 388.

[iii] R. Weber, *Pogg. Ann.*, cxlvii, 113; *Berl. Chem. Gesell.*, 1872, 804.

[iv] Berthelot, *Bull. Soc. Chim.*, 1873; *Ber. Chem. Gesell.*, 1873, 1560.

[v] *Zeit. Anal. Chemie*, 1867, 71; *Wagner's Jahres.*, 1867, 197.

[vi] *Jahresber. Phys. Vereins Frankfurt*, 1866-67, 18; *Wagner's Jahres.*, 1868, 254

According to Reichardt,[i] 1 part of nitre dissolved in 1000 parts of water gives no reaction with the aniline solution, whilst 1 part of nitre in 100,000 parts of water gives a very distinct coloration with brucin.

For the determination of small quantities of nitric acid in potable waters, a great number of methods have been proposed. Recently, F. Tiemann[ii] has made very accurate comparative experiments on the determination of nitric acid in the analysis of water. He arranges all the methods in four classes.

I. Methods which depend on the transformation of the nitric acid into ammonia in an alkaline solution and in presence of a metal. F. Schulze[iii] first based the method upon this principle, and effected the reduction by platinized zinc. Wolf,[iv] Harcourt,[v] and Siewert[vi] employ zinc and iron filings; Bunsen,[vii] a spiral of zinc-iron; and Chapman,[viii] aluminium-foil. In all these cases the ammonia generated is isolated by distillation, and if in large quantity, determined by means of a standard acid, but if in small traces, by means of Nessler's test. According to Frühling's statements,[ix] confirmed by Tiemann, the methods based upon this principle give inaccurate results in presence of organic matter. Finkener[x] observed that all the nitric acid was decomposed, but that in no case was all the nitrogen completely converted into ammonia.

II. Determination of the nitric acid by reduction to nitric oxide and re-conversion into nitric acid. This method, proposed first by Schlösing,[xi] and then modified by Reichardt,[xii] depends on the reduction of nitric acid to nitric oxide by the action of ferrous chloride and hydrochloric acid, oxidation of the nitric oxide to nitric acid by means of oxygen and water, and titration of the acid with a dilute soda solution. Schlösing receives the nitric oxide gas over mercury, whilst Reichardt applies soda-lye, which, according to his experiments, absorbs mere evanescent traces of nitric oxide.

---

[i] *Arch. Pharm.* [2], cxlv, 108. *Jahresber. d. Chemie*, 1871, 893.

[ii] *Ber. Chem. Gesell.*, 1873, 1034.

[iii] F. Schulze, *Chem. Centralblatt*, 1861, 657 and 833.

[iv] Wolf, *Chem. Centralblatt*, 1862, 379.

[v] Harcourt. *Chem. Soc. Journ.*, xv, 385.

[vi] Siewert, *Ann. Chem. Pharm.*, cxxv, 293.

[vii] Bunsen. *Zeit. f. Analyt. Chemie*, 1870, 411.

[viii] Chapman, "Sutton's Volumetric Analysis," second edition, 80.

[ix] Frühling, "*Landwith. Versuchsst.*," viii, 473.

[x] Rose, *Anal. Chem.*, sixth edition, ii, 829.

[xi] Schlösing, *Ann. Chim. Phys.* [3], xl, 479; *Journ. Prakt. Chem.*, lxii, 112.

[xii] Reichardt, *Zeit. Anal. Chemie.*, 1870, 24.

III. Methods which determine nitric acid by measurement of the nitric oxide evolved. Walter Crum,[i] as also Frankland and Armstrong,[ii] decompose the nitrates in a highly concentrated solution by concentrated sulphuric acid, and reduce the liberated acid to nitric oxide by agitation with mercury. Crum measures the nitric oxide in the decomposition-tube, whilst Frankland and Armstrong make use of a gasometric apparatus. Like Schlösing, F. Schulze[iii] decomposes the nitrates with hydrochloric acid and ferrous chloride, and receives the nitric oxide, liberated on the application of heat over moist mercury, determining the quantity by measurement. This method, which, according to Wulfert[iv] and Tiemann, gives very accurate results, has been modified by the latter,[v] who employs soda-lye in place of mercury.

IV. Methods which infer the quantity of nitric acid present from its oxidizing action upon a solution of indigo. Marx[vi] mixes 50 c.c. of the water to be tested, with double its volume of pure sulphuric acid, and adds a dilute solution of indigo to the hot liquid until the color appears green. The effective value of the indigo solution is determined by means of a solution of saltpetre of known strength, the conditions being otherwise exactly alike. Tromsdorf[vii] takes only 25 c.c. of water and 50 c.c. of sulphuric acid; determines approximately the quantity of indigo required by a preliminary experiment, adds this quantity at once, and titrates up to the production of a green color. Goppelsröder,[viii] Van Bemmelen,[ix] Finkener,[x] and Fischer,[xi] have proposed various modifications of the method. According to Tiemann's experiments, the proportions indicated by Tromsdorf are best adapted for practical execution. The determination of nitric acid by means of indigo always yields, however, inaccurate results if the water under examination contains large proportions of organic matter readily oxidizable. The prejudicial effect of such constituents may be partially, though not completely, removed by previously treating the water with permanganate.

---

[i] Crum, *Ann. Chem. Pharm.*, lxii, 233.

[ii] Frankland, *Chem. Soc. Journ.* [2], v, 6, 77.

[iii] Schulze, *Zeit. f. Analyt. Chemie*, 1870, 401.

[iv] Wulfert, *Dissert. T. Phil. Fac.*, Rostock.

[v] Tiemann, *Ber. Chem. Gesell.*, 1873, 1041.

[vi] Marx, *Zeit. für Annal. Chem.*, 1868, p. 412.

[vii] Tromsdorf, *Ibid.*, 1870, p. 171.

[viii] Goppelsröder, *Ibid.*, 1870, p. 1.

[ix] Van Bemmelen, *Ibid.*, 1872, p. 136.

[x] Rose, *Anal. Chemie*, ii, p. 831.

[xi] Fischer, *Journ. f. Prak. Chemie*, 1873, p. 57.

Nitric acid is employed in many branches of industry. The manufacture of coal-tar colors requires nitric acid for the preparation of nitro-benzol, binitro-benzol and nitro-toluol, from which, as is well known, the various aniline dyes of commerce are elaborated; for the separation of phosphin (chrysanilin) from magenta residues; for the oxidation of anthracen to anthraquinon; for nitrising naphthalin and phenylic alcohol. The conversion of arsenious into arsenic acid is in most establishments effected by means of nitric acid. Large quantities of nitric acid are also employed in the manufacture of sulphuric acid, of nitro-glycerine, of gun-cotton, of silver nitrate, and for the preparation of hare- and rabbit-hairs for the use of hatters.

On the Practical Utilization of Nitrous Oxide Gas. By Dr. OSCAR LIEBREICH, Professor of Medicine in the University of Berlin.

Whilst scientific chemistry in its ceaseless activity produces new substances in rapid succession, and by the charm of this fruitful energy continually acquires creative disciples, we recognize the strange phenomena that medicine tests in a very deliberate manner these substances. each of which exerts upon the animal economy an influence, even though not invariably capable of useful application. The want of good methods, the exceeding difficulty of deciding upon the benefit produced, especially since it is necessary in the human subject to contend with great idiosyncrasies in different individuals, explain this phenomenon. Thus it occurs that bodies which have long been known to the chemist under various points of view, suddenly acquire an increased signification when their utility has been proved in another department. This occurrence is rarer in technology than in medical science. One of the bodies which have acquired a new interest by some practical application is nitrous oxide. No longer a mere laboratory product. it is now, like other medicinal agents, prepared on the large scale.

Nitrous oxide is formed in many reactions. It is a product of the treatment of granulated zinc with nitric acid, or by adding the same acid to a hydrochloric solution of stannous oxide. On the large scale, however, the only method used for obtaining the gas is the application of heat to the nitrate of ammonia. As absolute purity is required for medical purposes, the use of a pure salt is important. The kind obtained by neutralizing pure carbonate of ammonia with pure nitric acid should be free from chlorine and from sulphuric acid. The well-known reactions with nitrate of silver and chloride of barium show the purity of the materials to be employed. The development of the gas begins at 170°. The chief art in the manufacture consists in the regulation of the heat, which must be moderated when the liberation of the gas commences. If the charge is overheated, nitrogen and ammonia are formed, as well as nitric oxide, the most dangerous by-product if inhaled. Even the gas obtained from pure materials, and with the utmost care, requires purification, which is best effected by a passage through a set of washing-bottles, charged with sulphate of iron, potassa-lye, and milk of lime. Any nitric oxide formed is destroyed by the sulphate of iron, acids are retained by the potash and carbonic acid; the least dangerous purity is further absorbed by the milk of lime.

The organs of dentistry describe minutely the apparatus required, which possesses for chemists no novelty, since it is the same which has been employed in laboratories for the preparation and purification of the gas. In most cases dentists prepare the gas for themselves, but in Berlin an apothecary, Herr Worf, occupies himself with filling gasometers for dentists.

The compression of the gas for sale must be mentioned as a new and interesting feature. This practice was first carried out in London according to Evans' process. The gas used for compression is prepared as above described, and received in iron bottles (about 40 centimetres long by 15 wide) provided with a strong screw-valve. The largest quantities are prepared in London by the mechanician, J. Orchard, Jr., of Kensington, and Messrs. James Coxeter & Son, of Grafton Street, through whose hands the cylinders are supplied, have had the kindness to communicate certain figures showing the enormous amount of the consumption. There were sold in—

1871, ...	146,211	gallons.
1872, ...	214,478	"
1873, ...	202,252	"

The decrease in the year 1873 is explained by a death during narcosis (*British Journal of Dental Science*, Feb., 1873).

The rapid circulation of this calamity through the press discouraged the public. Whilst in January, 1873, 23,000 gallons were sent out, the sale in the month of February, when this misfortune occurred, fell to 10,900; but it has subsequently increased again in an intensified proportion.

In Germany the compressed gas has been introduced by the well-known firm, Ash & Son, of Broad Street, London. No special establishments for the manufacture of the gas are in Germany.

After the discovery of nitrous oxide by Priestley, in 1776, it was more closely examined, in 1809, by Davy,[1] and its essential properties determined; the compression of the gas to a liquid was, however, first effected by Faraday. Davy observed that the gas, if respired, produced in man a peculiar condition, and this experiment has since been often repeated with confirmatory results. A peculiar excitement appears; the senses disappear at the first inhalations, and a singular drumming is felt in the ears. The body experiences a peculiar sensation of comfort, and the observer recognizes the symptoms of merriment. The name of laughing-gas was therefore given to the gas by Davy, on account of these properties, although in certain rare cases the excitement may pass over from cheerfulness to the opposite state of sadness. On continued respiration complete unconsciousness occurs, and finally death. This power of the gas to produce unconsciousness, discovered by Davy, was not practically utilized till later. In 1844, two years before the introduction of chloroform by Simpson Horace Wells, a practical dentist applied nitrous oxide to himself, the narcosis being conducted by the chemist, Dr. Colton. The new process, however, did not come into extended use prior to 1863. Narcosis for the extraction of teeth was often resorted to by dentists under Colton's superintendence, and in 1867 it came to the knowledge of the celebrated dentist, Evans, of Paris. From this time the scientific utilization of the method must be dated. On March 31st, 1868, the gas was tried by Evans on several patients in the Dental Hospital of London, and by the donation of £100, means were provided for testing the merits and defects of the process. The first report[1] on its results for dental purposes was very satisfactory, especially as regards a large number of cases conducted by Woodhouse Braine.[i] The gas now came into increasing use also on the Continent.

---

[1] Chemische und Physiol. Unters. über das oxydirte Stickgas u. das Athmen in demselben, von Humphrey Davy. Aus d. Eng., 1812–14.

[1] First Report by the Joint Committee of the Odontological Society of Great Britain, and the Committee of Management of the Dental Hospital of London, to

Various apparatus were required to facilitate the inhalation of the gas. There are simple mouthpieces through which the gas streams, and there are more complicated ones which permit the simultaneous entrance of air. There are also gasometers of special construction for receiving the needful quantity of gas. A large selection of such contrivances may be seen in the establishment of Messrs. Ash & Son.

As regards the application of the gas, it has been ascertained with certainty that the narcosis thus produced can be used only in such cases as require a short insensibility to pain. For dental operations the gas is, therefore, peculiarly suited. For more extensive operations in the cavity of the mouth, it is less to be recommended. With skilful management it is possible greatly to reduce the stage of excitement, or to get at once beyond it. A great advantage, as compared with other anæsthetics, is that a tendency to vomit scarcely ever appears at the first inhalation. The action of the heart is scarcely affected, and after the readmission of air the insensibility of the patient quickly disappears, and the general condition of the system is entirely normal. Attempts have been made to operate with mixtures of nitrous oxide and other narcotics. Thus, C. Sauer (*Vierteljahrs f. Zahnheilkunde*, iv Heft, 1869) has experimented with nitrous oxide and chloroform. An instructive treatise on the use of nitrous oxide gas alone for dentists, has been published by Dr. C. Grohnwald.[ii]

Although the practical application of this agent has been found useful, we have but few and insufficient facts towards a scientific explanation of its action. It seems that nitrous oxide does not give up its oxygen for combustion, and does not enter into chemical combination with the red blood-globules, since, as Nawrocki has shown, its absorptive relations for blood and for water are almost identical. On respiration, dyspnœa and asphyxia are produced just as on the inhalation of other indifferent gases, but the sense of suffocation is masked by the peculiarity of the intoxication. We must content ourselves with seeking the explanation of the action of the gas in the

---

inquire into the value and advantage of the protoxide of nitrogen as an anæsthetic in surgical operations. *Trans. Odont. Soc. of Great Britain*, i, No. 2.

[i] Braine, *loc. cit.*, No. 7.

[ii] Grohnwald. "Stickstoffoxydulgas als Anæstheticum." Berlin, 1871.

fact that it suppresses the function of the gangliar apparatus of the brain. Direct action upon the nervous organs of the heart has not been traced. Slight as are these scientific data, they yield valuable indications for its application, which correspond with practical experience. In the first place, the gas must not be inhaled for a long time consecutively; secondly, it is advantageous to mix with it at least one-tenth volume of atmospheric air; the longer the narcosis is required, the more air must be admitted, though the proportion must not exceed quarter volume. Especial attention must be paid to the respiration of the patient. That even with this method of inhalation unfortunate results occur need not surprise us, since from incidents not hitherto explained the use of almost every anæsthetic has demanded its victims. The statistical numbers published testify for its relative safety.

It cannot, however, be denied that the complication of the arrangements required for inhalation is an inducement to seek for new agents suitable for the purposes of dentistry. Thus the author has successfully applied, both in short and protracted operations, ethyliden-chloride, which, according to Hofmann, is abundantly formed as a by-product of the formation of chloral from alcohol. It has also been found suitable for dental operations by C. Sauer, of Berlin, in a long series of experiments.

[To be continued.]

NOTES ON SOME POINTS IN BOILER-MAKING.[1]

By Robert Briggs, C. E

The recent inspection, by the writer, of a proposed standard drawing of a common external fired tubular boiler, such as now has so general usage in this country, brought to notice two errors of construction in general, almost universal, practice, which it may be of some avail to discuss. In the example referred to, there was shown a flat-headed steam dome, with stays, to strengthen it, running down to the sides of the dome diagonally. The steam pipe was taken off from the middle of this flat dome sheet. Now it may be admitted that the staying of sheet, which was three feet in diameter, was ample for the pressure proposed to be carried, so that the conditions for *use* of the boiler were abundantly fulfilled; but it is contended that equal strength could have been had by giving the proper form to the head sheet without staying at all. Thus it is perfectly well known that the strength of a spherical shell, or of any portion of a spherical shell, is twice as great as that of the shell of a cylinder of the same diameter, when both shell and cylinder have the same thickness; or, on the other hand, that a spherical shell, or part of a spherical shell, possesses the same strength as a cylindric shell of the same thickness, when the radius of the spherical surface is equal to the diameter of the cylindric one. In this last case, when the rule stated is applied to the head of the dome or end of the boiler, which head is *formed* to a part of a spherical surface whose radius is the diameter of the dome or boiler, the head or end is "dished" out 0·134 time the diameter of the head or end. A three-foot heat requires to be *dished* only 0·4 of a foot (about $4\frac{13}{16}$ inches) in order to give the same strength to resist internal pressure, for both head and shell, of the same thickness of iron. A little allowance is needed for the thinning of the sheet iron in *dishing* in such case, as it may be thought proper that the thickness be preserved to the equality with that of the shell. This allowance is easily computed. The surface of the flat circular plate is, to that of the dished plate, as 1 to 1·072. That is, the thickness of the circle, before dishing, should be about 7 per cent. greater than that of the iron of the shell. This extra thickness, however, is a refinement of the boiler-maker or user, who would sell or buy the cheapest boiler consistent with full requirements for strength; as the flanging of the head will inevitably upset the flange itself to a thickness much above the original one, so that a dished head, as above described, of iron of ordinary shell thickness, will be much stronger than the shell sheets at the joints, where they are weakened by the rivet holes, even with the double-riveted longitudinal seams.

---

[1] From the *Polytechnic Review*.

These considerations apply more particularly to boiler-making in America, where it would be difficult to procure iron so poor that it would not dish readily without impairment of strength, such iron being capable of flanging at any heat; yet the same reasoning applies to English boiler work; although the frequent use of egg-end boilers seems to indicate that the argument here advanced has not been entertained or appreciated. In this country, certainly, it is pure waste of money to make a flat stayed head, when a dished one will answer.

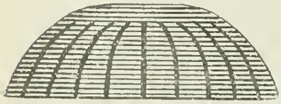
The next point to be noticed is the use of cast iron bonnet manhole rings on the cylindric portion of a boiler when a manhole is wanted on such a surface. First, within some reasonable limit of curvature, it can be affirmed that a bent manhole is just as good for service as a flat one. For shells of $3\frac{1}{2}$ feet in diameter and above, this is absolutely true. Double clips are always better than one; but with one clip, it is practicable to make as good a joint as any steam engineer may desire with such bent manholes, and a rubber, or, what I prefer, a hemp-plait gasket filled with red and white lead (with a little litharge if in a hurry). Secondly, for all places, both curved and flat, a wrought iron manhole ring is better than a cast iron one. It is safer, easier to make up to the boiler, and when the difference of weight is considered, it is nearly, if not quite, as cheap as a cast iron ring piece. Care should be taken to make the wrought iron rings heavy enough. Most of the failures to use them have been occasioned by *saving* in material; but material enough to give strength to the boiler, where it has been weakened by the manhole, is ample for all purposes, and the dimensions to supply this strength are easily computed. Suppose the manhole be 10×14, and imagine a shell $\frac{7}{16}$ thick. The weak place of such a hole is the 14 inch way, if it is longitudinal to the cylinder. There have then been removed from the shell $14 \times \frac{7}{16}$ or $6\frac{1}{8}$ square inches of material, whence, for bare strength only $3\frac{7}{16}$ square inches of iron should be found at each end of the manhole. $2\frac{1}{2} \times 1\frac{1}{4}$ give $3\frac{1}{8}$ square inches of section, and adding to the width $\frac{3}{4}$ for the rivet-holes in the ring, this ring becomes $3\frac{1}{4} \times 1\frac{1}{4}$. This dimension is the least that should be used in this case, and it will be found ample for the jointing of the manhole plate. Little deduction should be made in case the hole is made transverse to the shell. Here the curvature of the shell begins to tell on the strength of the ring, and in such case double clips should be used for the plate.

Wrought iron manhole rings should always be riveted to the inside of the boiler.

If a cast iron bonnet, manhole ring, or flange boss, is to be riveted to a boiler, it is very desirable to have heavy flanges; quite twice as heavy as usual for flange joints with bolts, and then it is advisable to rivet a thin plate $\frac{1}{8}$ or $\frac{3}{16}$ thick between the casting and the shell of the boiler, so as to form a calking strip to drive against; but in these days of cheap wrought iron, cast iron attachments to boilers, either nozzles, bonnets or rings, have become almost inexcusable cheapenings. Boiler-makers will also find out, at some time, that wrought iron flue doors, and even fire and ash-pit doors, properly made on formers, are handsomer, more durable, and nearly as cheap, as the ponderous castings which have heretofore disfigured fire fronts.

KENNEDY'S SPRING PISTON.[1]

FIG. 1.



This invention consists of a cup of brass, or other suitable metal, of the form shown in Fig. 1, and of somewhat larger diameter than the bore of the cylinder in which it is to work. The sides of the cup being slotted, form a series of springs having the outer ends free, but connected at the inner ends.

FIG. 2.

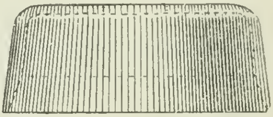
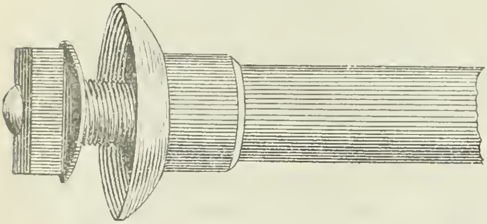
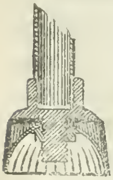


FIG. 3.



This spring cup is placed within the ordinary leather cup packing, Fig. 2, and together are secured to the piston rod by means of a shield casting and nut, seen in Fig. 3. The complete piston, Fig. 4, being inserted in the cylinder, the springs press against the leather packing, holding it firmly against the walls of the cylinder, preventing it from crimping or folding, as is often the case in the old form of piston.

FIG. 4.



This form of piston also has the advantage of adjusting itself to considerable imperfections in the bore of the cylinder, arising from wear or from dents, where the cylinder is formed of sheet metal, as in garden syringes, etc. It is obvious that the piston may be put on the rod either side up, adapting it to either lifting or forcing single-acting pumps, or to double-acting pumps, by placing two such pistons back to back on the same rod.

It also seems especially adapted to pumps that are only used at considerable intervals, as the springs prevent the leather from shrinking away from the pump cylinder when it becomes dry, and which would cause troubles when the pump is started again.

---

[1] Presented at the meeting of the Franklin Institute, May 15th, 1878.

Magnetic Iron.—Donati Tomasi passes a vapor current, under a pressure of five or six atmospheres, through a copper tube of two or three millimetres diameter. The tube is rolled spirally around a small iron cylinder, which becomes so strongly magnetic that a steel needle placed at some centimetres distance is powerfully attracted. The magnetism continues as long as the vapor current is maintained. —*Les Mondes.* C.

Maiche's Diaphragm.—L. Maiche proposes to correct the timbre of the telephone in the following manner: "I stretch before the magnetized bar a caoutchouc membrane, not exceeding four centimetres in diameter, with a thickness of one millimetre. To the centre of this membrane I glue a disc of tinned iron of at least the same thickness, having a diameter of three centimetres, and I cut the caoutchouc, on the side towards the magnet, over a diameter a little greater than that of the magnet. The caoutchouc being well stretched, it can be placed at less than one millimetre from the magnet. I thus combine two seemingly opposite conditions: 1, a thickness of iron sufficient to react properly upon the magnet, and to develop currents of sufficient intensity; 2, a vibratory sensibility which enables me to collect extremely feeble sounds; moreover, the voice which is heard is precisely that of a person speaking at a distance of a few metres. The timbre undergoes no change, all the gradations being preserved in the most perfect manner."—*Les Mondes.* C.

Official Paper.—Prof. Reuleaux recently gave a discourse before a commercial meeting at Leipsic, upon the character of the paper employed in the public offices, which he regarded as a striking evidence that the giving of contracts to the lowest bidder exerts an injurious influence. The paper which is now delivered consists almost entirely of wood, and in the course of ten or fifteen years we may reasonably anticipate that the official records, which are of the greatest importance to our families, will be destroyed through the natural processes of decay. Such a serious evil would seem almost incredible if it was not sustained by weighty evidence. But as long as our officials hold to their present course, and so long as they buy only what is cheapest, and what, as a necessary consequence, is also bad, we have no right to anticipate any improvement.—*Pap. Zeit.* C.

Niello.—The composition of the Russian tula, or Niello silver, has been hitherto kept secret. According to the *Berliner Tagblatt*, the firm of F. Zacher & Co., in Berlin, have discovered the method of manufacture, and have made it in large quantities. It consists of nine parts silver, one part copper, one part lead, and one part bismuth, which are melted together and saturated with sulphur. This mixture produces the gorgeous blue which has often been erroneously spoken of as steel blue. C.

Internal Magnetism.—M. J. M. Gaugain, from experiments upon steel tubes and nuclei, concludes that the changes of magnetism which are produced, under the influence of heat, in a solid steel bar, do not differ from those which are produced, under the same influence, in a system composed of a tube and a nucleus. Both seem to depend on the inverse magnetism developed by the mutual reaction of consecutive layers, either of the bar or of the system.—*Comptes Rendus.* C.

Dimensions of Lightning-Rods.—Dr. Nippoldt, in a note from the Paris Observatory, objects to the dimensions proposed by Kuhn. Designating by W the heat developed in the rod, I the intensity of the current, r the specific resistance of the conductor, l its length, g its section, s its density, w the specific heat, M the mass, t the temperature, he deduces, by electro-dynamic laws, the equations:

$$t = \frac{W}{t g s w} = \frac{I^2 r}{g^2 3 w}.$$

The temperature is, therefore, independent of the length of the conductor. The metals commonly used are the following:

	w.	s.	r.
Iron, . . .	·1138	7·75	·0986
Copper, . .	·0951	8·95	·0162
Lead, . . .	·0314	11·35	·0199
Platinum, . .	·0324	21·54	·0918

If we adopt 144 square millimetres as the proper section for an iron rod, copper would require 90 sq. mm.; lead, 320; platinum, 156. In these estimates the copper is supposed to be absolutely pure. According to Matthiessen, the pressure of ½ per cent. of iron trebles the resistance. C.

Formation of Whirlwinds.—In Hebert's recent communications to the French Academy, he has laid special stress upon the influence of the land configurations, and especially of the mountains and valleys, upon the great movements of the atmosphere. He comes to the conclusion that all the cyclones which visit Europe from the Atlantic Ocean originate in the American mountains. Many years ago, Professor Henry indicated the region of the Saskatchawan as a prominent cradle of storms. More recent communications to the American Philosophical Society, based partly upon the observations of the Signal Service Bureau, and partly upon special meteorological records at San Francisco and at Barbadoes, have shown that there are two other important centres of extensive atmospheric disturbance: one in the neighborhood of Colorado, and another in the West India Islands. C.

Transmission of Power.—At a late meeting of the Société Francaise de Physique, M. Cadiat explained a method by which he had succeeded in transmitting the movement of a steam engine to a distance of 150 metres, by coupling two Gramme machines, the second being made to turn by the current which is produced by the first. C.

New Telephone Diaphragm.—Louis Ollivier, of Elbeuf, believes that the flat form of the receiving diaphragm interferes with the proper reproduction of the vocal *timbre.* This timbre is produced by the more or less complete blending of different harmonics. Helmholz, by the aid of his resonators, has been able to isolate, successively, the fundamental tone and the different harmonics. After having thus analyzed the sounds, he has recombined them by synthesis. In order to have a diaphragm which may vibrate in unison with various harmonics, Ollivier uses a concave plate of varying thickness, imitating, in some respects, the tympanum of the ear. —*La Nature.* C.

Homogeneous Cast Steel.—The discussions of Gautier and Euverte, upon the influence of silicium in iron, have led to a special investigation by F. Osann, who finds that a very small quantity of silicium offers the best protection against the undue oxidation of the carbon, and the consequent undesirable production of gas and blisters, which interfere with the solidity and homogeneity of steel. —*Zeits. des Ver. Deutsch. Ing.* C.

Darien Canal.—Guzzi and Ravizza invite the special attention of Italian engineers to the proposed American inter-oceanic canal, on account of the increasing prospective importance of Italian commerce. They give an excellent summary of pamphlets, which have been published in France, Italy and America, and of the different propositions which have been made for traversing the Isthmus.—*Il Politecnico.* C.

Electric Meteorology.—In the Atti della R. Accad. di Napoli for 1877, Palmieri gives a *resumé* of his twenty-seven years' observations upon atmospheric electricity, and a description of his principal instruments of observation. By means of simultaneous observations at the University Observatory and at Capodimonte at Naples, as well as at the observatory on Vesuvius, and by comparisons with observations on the Little St. Bernard and in Moncalieri. he finds that in dry, clear air, where the distribution of positive atmospheric electricity is normal, the strength of the influence diminishes with increasing height. This result is different from that which has been obtained by other observers, which he explains by stating that comparisons should not be made between conductors of different lengths, but that similar conductors and instruments should be watched simultaneously at different heights. C.

Daily Barometric Variations.—Renou thus explains the normal daily variations of the barometer. The sun warms the atmosphere which turns beneath it, producing a disturbance over an entire great circle, of which the hottest point is the pole. This effect ceases soon after the maximum temperature, about 4 P. M., producing a maximum pressure at points 90° distant, corresponding respectively to 10 A. M. and 10 P. M. The atmospheric wave which produces this effect follows the apparent movement of the sun with a velocity of 464 metres per second, at the equator. The direction of this wave should produce a greater maximum in the morning than in the evening, and it should also be affected by the easterly or westerly direction of the winds. The night minimum is merely a relative minimum, comprised between the morning and evening maxima. The barometric mean at 4 A. M. should then differ but little from the mean of the whole day. It is, however, some fractions of a millimetre lower, in consequence of the loss of weight from the deposition of dew.—*Comptes Rendus.* C.

Interference of Electric Explosions.—De Waha has found that the interference rings of electric explosions, when observed under the microscope, seldom appear single; but the broad interference mark appears to be overlaid with darker linear rings. He, therefore, concludes that every explosion is accompanied by numerous successive partial explosions or partial sparks. A writer in the *Beiblätter*, suggests that these phenomena correspond to the electric oscillations. De Waha measured the interval between two successive sparks, in a single instance, and found it to be about one four-millionth of a second.—*Beibl. Annal. der Phys. u. Chem.* C.

Discharges in Geissler Tubes.—De la Rue and Müller have been investigating the electric discharge in tubes containing rarefied gas. Among other results they find the following: 1. The discharge in rarefied gas does not differ from that which takes place in air or other gases at atmospheric pressure. It is not a current, but a disruptive discharge, the gaseous molecules effecting a transfer of electrization. The gases probably receive two impulses in opposite directions, that which comes from the negative electrode being most continuous. 2. As the pressure diminishes, the electromotive force diminishes at first, and then increases until a pressure is reached which no electromotive force can traverse. 3. All the strata originate at the positive pole. 4. If the electromotive force is uniform, the phenomena depend upon the intensity of the current. 5. A change of intensity often produces a complete change in the color of the strata. 6. By gradually modifying the intensity, many successive phases of stratification may be obtained, alternately fixed and wavering. 7. The heat is greatest in the neighborhood of the strata. In the obscure portions of the tubes there often appears to be a kind of calorific stratification. 8. Even when the strata are immovable, a regular pulsation may be observed in the current, by means of a telephone or an induction coil. But it does not appear that the strata depend upon these intermittences. 9. The current will not traverse a tube closed by a glass partition. Such a tube can only be illuminated by alternate discharges. 10. Changes of intensity and pressure give a great variety of phenomena, but all the effects are constant, and can be reproduced in tubes of the same dimensions under the same circumstances. 11. If the pressure and current are constant, the diameter of the tube influences the character and distinctness of the stratifications.—*Comptes Rendus.* C.

Economical Value of Solar Heat.—In experimenting with his solar heating apparatus, Mouchot has found that the most satisfactory material for mirrors is either silver or brass, covered with a thin layer of silver by galvanizing. The variations of solar intensity in Algiers, between 8 A. M. and 4 P. M., are generally slight. The quantity of heat gathered on a square metre, per minute, varies from 6 to 9·8 calories. A supply of seven calories enables a reflector of a metre square to boil, in less than twelve minutes, a litre of water at 20°, and produces hourly 778 grammes, or 1322 litres, of steam at the normal pressure. These results are only two-thirds as great as he anticipates from larger receivers. He proposes soon to present to the academy a description of his great receiver of twenty-five square metres, which is to be placed in the Universal Exposition.—*Comptes Rendus.* C.

Deterioration of the Tubular Girders of the Britannic Bridge.—In replying to some remarks in the *Standard* of the 18th inst., on this subject, Mr. Edwin Clark writes: "I was in the habit, for many years, of carefully inspecting the bridge, and in 1866, I was officially requested, in conjunction with Mr. Hedworth Lee, the resident engineer of the London and Northwestern Railway Company, to make a very thorough examination, both as regards state of preservation and its deflection. The result is given in a paper read by myself, at the Institution of Civil Engineers, 'On the Durability of Materials,' vol. xxvii, session 1867-68. After describing the constant care with which its preservation had been attended to, and stating that not the slightest increase of deflection could be detected, the following quotation occurs:—'The author does not hesitate to express his firm belief that the total loss from rust of the whole 10,540 tons, of which the bridge consists, has not in twenty years amounted to a single pound weight. If similar care is continued it is impossible to conceive how any practical deterioration can take place in such a structure, even in several centuries.' This is so completely at variance with the singular statement of the gentleman you quote that I can only imagine the tar and sand with which the cells are internally coated, and which is from time to time cleared out, has been mistaken for iron-rust; but the interior of the cells was at that date absolutely free from any trace of oxidation." Mr. W.

Baker, engineer-in-chief of the London and Northwestern Railway, has also written to the same effect.—*The Engineer.* *

The Electric Fuse and Heavy Cannon.—It seems as if we were about to abandon the old method of firing guns on board ship with the lanyard, and to use the electric fuse instead, at any rate, so far as heavy cannon are concerned. For some years past experiments have been carried on in the navy with electric firing, but it is only since we have had to do with very heavy guns, and particularly those in turrets, that this method of discharge has become almost indispensable. To be cooped inside a close iron turret in company with a pair of terrible weapons of 35 or 38 tons, and to experience the full measure of their thunder, is scarcely to be contemplated with indifference; yet this is not the reason, or at least not the principal reason, why the electric current is to be employed in the future instead of the gunner's arm. The real cause is twofold; in the first place it is possible to take better aim by using electricity to do the work; and, secondly, the effect of the shots are more terrible. The simultaneous discharge of three or four projectiles against heavy armor has been found capable of penetrating the latter, when single shots are quite unable to do so. A vibration is set up in the iron plating, it is presumed, and in this condition the armor is more vulnerable. Simultaneous firing is impossible by hand and word of command, in the same way as gunners used to fire broadsides in the old three-decker days. To the ear the thunder of discharge might appear instantaneous, but the effect upon an ironclad is vastly different if a volley is fired by lanyards, or by a flash of electricity. The other reason is more important still. The guns are so close to the water, and the portholes so limited in size, that sighting along the weapons is frequently a matter of difficulty. The operation is much more easily performed by an officer stationed above, either in the rigging, or in the armored tower, with which most of our modern ironclads are fitted. Provided with suitable sights and electric wires which lead down into the batteries, the captain, or other officer of the ship, here has the whole of its armament under his hand. He directs at what angle the gun shall be laid, and watching his opportunity, discharges them simultaneously at the instant he thinks most fit. Situated above the deck he is removed from the bustle and smoke below, and can act with more coolness and judgment, while obviously no time is lost when the critical moment for firing arrives.—*Standard.* *

The Direct Process of Making Wrought-Iron.—The Dupuy process described in the JOURNAL for December, 1877, has been subjected to a test upon a commercial scale, by Messrs. Miller, Metcalf and Parkin of Pittsburg, who, in a letter to the inventor, dated June 7th, last, say:—"After a careful and thorough series of experiments upon the iron produced by your process, we have to report that it produced a fine steel, equal in quality to any of the best standard tool steels in the market, either foreign or American. It must be borne in mind that this iron was produced from the best magnetic ore we know of, charcoal as a deoxidizer.

"We have thus demonstrated the higher capabilities of your process, and, of course, it is safe to say that worse might be done. As you are well aware, our furnace was not adapted to a sure and economical working of your process owing to a defect in form, therefore we did not develop the commercial side of the process, and do not give any estimate of cost, because we feel that our figures would be unjust.

"Our belief is, that for steel of a very high quality your process could be worked economically in competition with the best Swedish irons." *

Inextinguishable Signal Lights.—Mr. N. J. Holmes has recently perfected an improved method of producing intermittent inextinguishable signal lights, which is fully described in the *English Mechanic* for May 31st. It consists in generating phosphuretted hydrogen from phosphuret of calcium in a closed vessel under pressure and, by means of an automatic discharging arrangement, obtaining flashing signals of definite duration and at fixed intervals of time.

In one form of apparatus for this purpose, a strong vessel is employed, into which the proper proportion of phosphuret of calcium, enclosed in a suitable receptacle, is inserted through a movable door at the side.

Upon the top of the vessel is secured a cock, the plug of which is rotated by a mechanical movement. This cock is so constructed that in one position of the plug, it opens a direct communication between the interior of the vessel and the air by which the gas may be discharged, and in another position admitting into the vessel a definite quantity of water—each passage being closed when the other is open. Thus, for every discharge of gas, only the equivalent of water is admitted sufficient to develop the next discharge; the frequency and direction of the discharges being regulated by the speed of rotation of the plug of the cock. *

Steel and Wrought-Iron Projectiles.—Experiments are to be resumed at Shoeburyness for the purpose of gaining information as to the penetrative power of steel and wrought-iron projectiles and the resistance of specially prepared targets. Some of the results already obtained have produced most unexpected and surprising experiences, the most remarkable being found during a trial of a composite steel and iron target. When fired against the steel face of the target, the projectiles broke up badly, but when the target was reversed the shot not only penetrated the softer wrought-iron, but went clean through the steel as well. This is theoretically accounted for by the supposition that in passing through the wrought-iron the metal of the projectile gets set up into a more compact body, and is therefore better able to endure the shock of the heavier impact. This discovery, if it be a discovery, is to be further investigated, and in order to test it in the opposite direction a steel projectile with a wrought-iron face upon it has been made at the Royal Laboratory Department, Royal Arsenal, Woolwich, and sent to Shoeburyness this week.—*Iron.* *

Engineers' Club of Philadelphia.—At a recent meeting of the Club, Mr. Wm. F. Sellers read an interesting paper on the Kentucky River Bridge of the Cincinnati Southern Railway. The river at this point is about 300 feet wide, and flows in the bottom of a narrow cañon, about 300 feet deep and 1300 feet wide. For numerous reasons a pier in the river was rendered impracticable; so it was decided to use three spans of 375 feet each, supported by abutments on each cliff, two iron piers in the cañon. The fact that the iron piers would vary in height with the temperature while the cliff abutments would not, made it obligatory that the spans should be so hinged as to permit of this vertical motion of the piers without altering the strains in the truss. To accomplish this it was decided to construct the bridge with a central span supported near each end by the piers, the overhanging portions being hinged to the end spans, the shore ends of which were supported by abutments.

The truss is 37½ feet deep, 18 feet wide, and each span divided into 20 panels of 18¾ feet each, and was erected without the use of any false works, which the height of the bridge and swift current of the stream precluded.

At the same meeting, Prof. Wm. D. Marks called attention to an improved form of Marquoi's Scale.[1] *

---

[1] See JOURNAL OF THE FRANKLIN INSTITUTE, vol. cv, page 418.

Book Notices.

REPORTS AND AWARDS OF THE INTERNATIONAL EXHIBITION, 1876. GROUP IV. Animal and Vegetable Products and the Machinery for their Preparation. 8vo., pp. 324. Price $1.50. J. B. Lippincott & Co.

The first impression produced upon reading the title of this group is that it should have been divided, as it requires an entirely different sort of knowledge to judge of machinery and of its products. This impression is confirmed upon reading the general report, for there is not a word to be found upon the "machinery."

The general report comprises 42 pages, and consists almost entirely of a history of the doings of the judges, together with some account of the sources from whence the exhibit came, but in no case is there a description of methods or processes employed in the preparation of animal or vegetable products.

There is, therefore, very little to be learned from the report that would tend to advance the industrial arts.

An examination of the reports on awards, covering the remaining 280 pages, discloses some of the difficulties of any system of awards which involves the necessity of selecting from the vast number of exhibits in such a group, any limited number to which awards should be made, or even commenting intelligibly upon each exhibit.

Out of 2727 exhibits named, there are 928 of wine alone and 465 of other fermented, distilled and malt liquors, cordials, &c. The result of the effort to make a descriptive comment on each of these results is an almost constant repetition of "good dry pale XX wine;" "very good dry pale XX wine;" "good sweet XX wine;" "excellent dry pale XX wine," &c.

Again, there are 81 exhibits of "coffee," on 40 of which the judges report "of very good quality," and on 13 "of superior quality—(extra) grain of regular size and color—rich in flavor."

Neither here or in the general report is one able to learn in what portion of the globe the best samples were grown.

GROUP V.—Fish and fish products, apparatus of fishing, &c. 8vo., pp. 47, price 25 cents.

The general report covers 23 pages, is well written, being principally a description of the general character of the exhibits, and in some cases, especially class 642 (pickled fish and parts of fish used for food), a discussion of the exhibits by nationalities.

In this class, France fully maintains the pre-eminence she has so long enjoyed, and exhibits from her manufactures "were rightly considered as standards of excellence."

The exhibits from Norway were very prominent in this class, almost every edible fish caught on the coast of "that country" was found.

The exhibits made by Portugal were of the most varied character, in fact exceeding in quantity that of any other country.

A comparison of the exhibits show that the kinds of fish preserved in the United States, are very few compared to other countries, but but whether this fact arises from prejudice or ignorance, the judges were unable to determine.

Descriptions are given of the American method of preparing canned salmon, and of preparing sardines in France, which, while short, are very instructive. *

THEORY OF TRANSVERSE STRAINS, AND ITS APPLICATION IN THE CONSTRUCTION OF BUILDINGS. By R. G. Hatfield, Architect. John Wiley & Sons, New York. Price $6.00. On sale by Claxton, Remsen & Haffelfinger.

This work, from the pen of the author of the "American House Carpenter," is intended to meet the wants of two distinct classes; in the first place, it is for those architects who desire to use better and more exact methods than those furnished by mere precedent, or simple guess-work, but have not had time or opportunity to acquire the requisite knowledge, and secondly, it is for students of architecture, and they will probably find in it an invaluable text-book.

The author does not presuppose any very great previous knowledge on the part of his reader, but beginning at first principles, he makes his formulæ and substantiates his conclusions by simple algebraic demonstrations, combining with them the results of experiments made by himself and others. His method has been, as he says in his preface, "To present an idea at first in its concrete form, and then to lead the mind gradually to the absolute truth, upon which the idea is based," while to enhance the value of the work as a text-book, each chapter is followed by a series of "Questions for practice," or practical examples, which will tend to fix, as well as to make more real and tangible in the mind of the student, the principles and proofs set forth in the preceding pages.

The work seems eminently practical, and considers, in turn, beams and girders of various forms and materials, discussing also the problem of solid wooden floors, suggested as offering more resistance to the spread of flames, and giving co-efficients for the strengths of different kinds of timber, derived from the author's own experiments.

Graphical representation is also made use of, and several chapters are devoted to the graphical expression of strains of various sorts, simple and compound, in levers and beams. Numerous valuable tables are given, which, together with a very complete index and a list of answers to the problems offered for solution, form the last 124 pages of the 630, which the work comprises.

These tables alone, if they are founded on reliable data, will make the book one of great value; nothing is more useful to the practical man than good tables which give at a glance, or without elaborate calculation, the facts for which he seeks. S., JR.

PRINCIPLES OF ELEMENTARY MECHANICS. Prof. De Valson Wood. 12mo, pp. 351. N. Y., John Wiley & Sons, 1878.

This little work will be very welcome to instructors, as it presents the most important laws of elementary mechanics in an exceedingly condensed and intelligible manner. Drawing all demonstrations from elementary mathematics, this work may be used to great advantage where there is no intention of taking the scholar through the higher branches.

To the student it will be no less welcome, as any one with a fair knowledge of algebra and plane trigonometry will be able to follow the very plain and brief demonstrations given, in most cases, without further aid.

While discarding the use of calculus, Prof. Wood does not fall into the opposite error of confusing the student with a quantity of assumptions to aid the demonstration.

A special feature of the work is the large number of exercises given, which afford the student good opportunities of practically applying his knowledge as he advances, and which relieve the teacher, in a great measure, of a very arduous duty. P.

RESOLUTIONS OF THE BOARD OF MANAGERS OF THE FRANKLIN INSTITUTE, ON THE DECEASE OF MR. BLOOMFIELD H. MOORE.

At a meeting of the Board of Managers, held July 10th, it was "*Resolved*, That, with sincere regret, this Board learns of the decease of Mr. Bloomfield H. Moore.

"Mr. Moore was elected a member of the Franklin Institute in 1863, and, for a period of over fifteen years, was actively identified with its interests.

"*Resolved*, That a committee be appointed to prepare a suitable memorial of Mr. Moore, to be entered upon the minutes of this Board, and to be published in the JOURNAL of the Institute."

On motion, the preparation of the memorial was referred to the Committee on Publication.

THE memoir of Mr. Moore will appear in the September number of the JOURNAL.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CVI. SEPTEMBER, 1878. No. 3.

THE Franklin Institute is not responsible, as a body, for the statements and opinions advanced by contributors to the JOURNAL.

ECONOMIC VAPORIZATION OF WATER AND EXPANSION OF STEAM.

Analysis of Mr. Lavington E. Fletcher's experiments at Dalkeith, Scotland, on the engine and boilers of the paper mill belonging to the Messrs. Craig.

By Chief Engineer ISHERWOOD, U. S. Navy.

The purpose for which the experiments herein analyzed were made, was to ascertain the economic efficiency of a water-tube boiler patented by the Messrs. Sinclair, of the Albion Boiler Works, Leith, and of an engine constructed by the Messrs. Bertram, of Leith Walk Foundry, Edinburgh. These experiments were conducted by Mr. Lavington E. Fletcher, the Chief Engineer of the Manchester Steam Users' Association, from whose report, on p. 129 of *The Engineer*, of Aug. 24th, 1877, the data are taken. Only the *observed* data have been taken; none of his calculations or deductions have been used, but in their place entirely different ones have been substituted, so that he is responsible for nothing in this paper except the accuracy of the quantities obtained by direct measure, weight or count.

As the records of steam engineering contain but few experiments in which the weight of both the feed-water pumped into the boiler, and of the water delivered by the air-pump into the hot-well, was simultaneously ascertained, with the accompanying temperatures, pressures, etc., as well as the horse-powers developed by the engine, and the conditions under which the steam was used, it seemed to the writer that the lesson, so seldom given, was too valuable to neglect; and he has, therefore, analyzed these experiments from his own point of view, to ascertain what they really taught. It is to little purpose that experiments are made, if their reports are to contain only the observed data, without reduction, analysis, and an exposition of the causes to which the effects are due. They should be made, too, in such a manner as to be correlated, so that truths not inferable from any isolated experiment can be deduced from a combination of several.

The experiments under review, when fully interpreted, give valuable evidence on one of the most important problems in steam engineering, namely, the relative economic efficiency of different measures of expansion for steam; but nothing in the original report states the fact that these experiments were made with different measures of expansion, the reader being left to obtain that knowledge from one representative indicator diagram given for each experiment; and it is on this single diagram that the writer has been obliged to depend for the fraction of the stroke of the piston completed when the steam was cut off, and for the back pressure in the cylinder resisting the piston. The number of indicator diagrams taken was entirely too small; one every half-hour from each end of the cylinder, with a cut-off valve regulated by a governor, and variable with the speed of piston, is not enough for experiments of only a few hours' duration; they should be taken every few minutes, and the mean point of cutting off given from them, as well as the mean initial pressure in the cylinder, pressure at the point of cutting off, final pressure, back pressure and indicated pressure. All these are most important quantities, not one of which can be omitted without incompleteness; they should be as accurately ascertained as the weight of water and coal.

The experiments were made both with and without steam in the cylinder jackets, and should have been available for solving the important problem of the economic value of the steam-jacket; but as no two experiments were made with the steam used with the same measure of expansion, they are useless for this solution, yet comparative results are presented without reference to the fact that, owing to want of equality in this condition, no comparison is possible.

Notwithstanding, however, defects of method, doubtless not within the control of the experimenter, the data of these experiments are well worth a careful examination.

ENGINE.

The engine consists of one horizontal, direct-acting cylinder, fitted with a jet condenser and an air-pump. The cylinder is steam-jacketed on sides and ends, and has a Dack's cut-off valve, regulated by a high-speed governor of the Porter type. There is no throttle-valve, and the steam admission is controlled by the cut-off valve alone, which is variable from zero to three-fourths of the stroke of the piston. The steam pipe delivers the steam direct into the valve-chest, and the steam-jackets are supplied with boiler steam by a small independent pipe. The cushioning of the steam, and the lead of the exhaust, are quite insignificant.

The following are the principal dimensions of the engine required to be known, in connection with the experiments:

Number of cylinders,	1.
Diameter of cylinder,	30 in.
Stroke of piston,	42 in.
Net area of piston, exclusive of piston-rod,	702·387 sq. in.
Space displacement of piston per stroke,	17·0719 cu. ft.
Space at one end of cylinder, in clearance and steam-passage, including capacity of valves,	1·1407 cu. ft.
Length of steam-port,	18 in.
Breadth of steam-port,	$2\frac{1}{4}$ in.
Area of steam-port,	40·5 sq. in.
Clearance of the piston,	$\frac{5}{16}$ in.

With this engine two boilers were alternately employed (only one at a time), namely, the Sinclair boiler and the common Lancashire boiler.

The steam-pipe connecting the engine with the Sinclair boiler, was 61 feet long, of which the first 23 feet were 7 inches in diameter, and the remainder 6 inches. In this pipe there were 7 elbows and an intermediate valve.

The steam-pipe connecting the engine with the Lancashire boiler, was 70 feet in length, and of the uniform diameter of 6 inches. In this pipe there were also 7 elbows.

Both steam-pipes were well covered with Fleming's composition.

SINCLAIR BOILER.

The Sinclair boiler consists of 2 parallel vertical flat water-spaces connected by nearly horizontal wrought iron tubes, beneath which is the furnace. The flat water-spaces form the front and back of the boiler, the sides and top of which are of brick masonry, enclosing the tubes and furnace. At the top of the flat water-spaces, connecting them, and lying parallel with the water-tubes, are two horizontal cylinders of boiler-plate at different elevations, the lower one being half filled with water and half filled with steam, while the upper one is wholly filled with steam. The flat water-spaces and all the water-tubes are solidly filled with water. The furnace has no crown, and the gases of combustion at once envelop the water-tubes over the entire exterior surfaces of which they are made to circulate by means of horizontal baffling-plates interposed between the tubes. The furnace-grate is 6 feet 7 inches wide, and 6 feet long, presenting an area of 39·5 square feet, and it is fired through two doors perforated for air admission, above the incandescent fuel.

The water-tubes are 105 in number, all of which are 11 feet 9 inches long between the flat water-spaces; 99 are of 4 inches external diameter, and the remaining 6 are of 5 inches external diameter. The 6 tubes are arranged 3 on each side of the furnace; and the 99 are arranged over the grate in 11 rows vertically, each row containing 9 tubes so placed that they are opposite the spaces between the adjacent rows above and below. The entire height occupied by the tubes, from the bottom of the lower row to the top of the upper row, is 6 feet 6 inches; and from the bottom of the lower row to the top of the grate bars, is 20 inches. From the top of the upper row to the bottom of the upper steam-cylinder, or reservoir, is 30 inches; this reservoir being placed over the centre of the boiler, and encased in the brick masonry, with the exception of the lower fifth of its periphery, which is exposed, as a steam-superheating surface, to the gases of combustion just before their exit into the chimney.

The remaining steam-cylinder, or reservoir, is placed upon one of the side walls; it has one-seventh of its periphery in contact with the gases of combustion, and nearly one-half of its periphery in contact with the atmosphere. The horizontal diameter of the lower reservoir is 2 feet below that of the upper one. Both cylinders are 4 feet in diameter and 16 feet 9 inches in length.

The flat water-spaces are strongly stayed, to resist the steam pressure.

The total water-heating surface of the boiler, calculated for the *inner* circumference of the tubes, is 1420 square feet, being 35·95 square feet per square foot of grate surface.

LANCASHIRE BOILER.

There were three Lancashire boilers situated by the side of the Sinclair boiler, and all four discharged their gases of combustion into a common flue. The Lancashire boiler experimented with was the one adjacent to the Sinclair boiler. It had a cylindrical shell, 7 feet in diameter and 25 feet 3 inches in length, set in masonry. This shell contained two cylindrical flues, of 2 feet 9 inches diameter, extending its whole length. The front end of these flues was occupied by the furnaces, whose grates were 6 feet 8 inches long. The aggregate grate surface was thus 36·6 square feet.

The gases of combustion, after leaving the furnace flues, returned on each side of the shell, to the front of the boiler, whence they descended into one common flue beneath the shell, and thence flowed towards the chimney at the back of the boiler. The flues at the sides and below the shell were made in the masonry of its setting.

The total heating surface was 698·5 square feet, or 19·08 square feet per square foot of grate surface.

FEED-WATER HEATER.

In the flue which received in common the gases of combustion from the Lancashire boilers and the Sinclair boiler, there was a feed-water heater, and, as the temperature in this flue was over 800 degrees Fahrenheit, that heater was very efficient. Although only one of those boilers was in use at a time, to supply the experimental engine, yet the others were in use for other purposes, and thus the temperature of the flue was maintained. The boiler in use for the experimental engine was shut off from the others by a stop-valve. The heater was used in only the first two experiments, namely, A and B in the following table; in the remaining three experiments, the feed-water was pumped directly from the measuring tank into the boiler.

MANNER OF MAKING THE EXPERIMENTS.

The experiments were made in the paper mills of Messrs. Robert Craig & Sons, at Dalkeith, Scotland; and each lasted during the middle portion of the working day. All the coal burned was weighed by Mr. Sinclair, the patentee of the boiler, who also superintended the firing. The thickness and condition of the fires at the end of an experiment were left the same as at the beginning, as nearly as could be judged by the eye. The water level and steam pressure were also left the same at the end as at the beginning of an experiment.

The measurements of the feed-water consumed were made by Mr. D. Crichton, R. N. Those of the water discharged from the hot-well were made by Prof. John Lockie, of Edinburgh. The indicator diagrams were taken every half-hour, from each end of the cylinder, by Mr. A. Masson, manager of the firm from whose designs the engine was built. Each of these gentlemen had assistants. The supervision of the entire experiments was by Mr. Lavington E. Fletcher, assisted by Mr. Richard Thompson, one of the inspectors of his Association. There was no lack of competent persons to secure accurate observations, and there is no doubt those recorded are scrupulously exact.

The feed-water was taken from the hot-well tanks and measured in an open tank of 4 feet cube, from which it was pumped into the boiler by a steam-pump placed immediately over the tank. The suction pipe of this pump reached to within a few inches of the bottom of the tank, and carried a scale of feet and inches, from which the depth pumped out could be at any moment noted. The tank was pumped out to within 6 inches of the bottom, and it was always filled to a fixed point, so as to give a depth of 2 feet 6 inches for each tankful. The time at which each tank was emptied was noted in a tabular log.

The water discharged from the hot-well was measured in two tanks, each 10 feet long, 4 feet wide and 3 feet deep, with a sluice-valve at the bottom for emptying. The water from the hot-well could be directed into either tank at will, and one was being filled while the other was being emptied. The tanks had covers in which were large manholes and a number of smaller holes kept open for freeing the air and vapor. The tanks were about 8 feet from the air-pump, and the time of filling one averaged about 6 minutes.

DESCRIPTION OF THE TABLE CONTAINING THE DATA AND RESULTS OF THE EXPERIMENTS.

The data and results of the experiments will be found in the following table, in which the columns—each containing an experiment—have been lettered, and the lines containing the quantities have been grouped and numbered, for facility of reference.

Experiments A, B and C were made with steam of the boiler pressure in the cylinder-jackets; and experiments D and E were made with the steam shut off from these jackets. In every experiment the steam was used with a different measure of expansion.

In experiments A and B, the feed-water, after being measured in the tank, was pumped through the heater, and received a considerable accession of temperature before entering the boiler. In the remaining experiments, the feed-water was pumped direct from the tank into the boiler.

Two kinds of coal were used. Welsh semi-bituminous, from the Duffryn mines, in experiment B; and Scotch bituminous, from the Marquis of Lothian's mines, in the remaining experiments.

The Sinclair boiler was employed in experiments A, B and E; and the Lancashire boiler in experiments C and D.

Experiment C would have been continued seven consecutive hours, but for a leakage from the blow-out tap at the bottom of the boiler, by which means 2½ hours were lost.

Line 1 contains the date of the experiment.

Lines 2 and 3 contain, respectively, the number of square feet of grate-surface and of heating-surface in the boilers.

Total Quantities.—Lines 4 to 13, both inclusive, contain the total quantities counted, weighed or measured.

Line 4 gives the duration of the experiments in consecutive hours.

Line 5 gives the kind of coal consumed.

Line 6 contains the total number of pounds of coal consumed, during the experiments, as given by careful weighing; the thickness and condition of the fires, the height of water in the boiler, and the steam-pressure on it, being supposed the same at the end as at the beginning of the experiments.

Line 7 gives the total number of cubic feet of feed-water pumped into the boilers, from a tank in which it was carefully measured.

Line 8 gives the weight of this water in pounds, obtained by multiplying the quantities on line 7 by the weights, respectively, of a cubic foot of water at the temperatures on line 20. These quantities are too small, by the amounts vaporized under the atmospheric pressure from the water-surface in the open tank.

Line 9 gives the total number of pounds of water of condensation withdrawn from the steam-jackets of the cylinder during the experiments. This quantity was obtained by measurement in a tank, and is, necessarily, too small, as the water within the jackets resulting from the condensation of the steam therein, had the temperature due to the pressure of that steam, and much greater than the temperature normal to the lessened pressure of the atmosphere into which it immerged, the heat due to the difference of the two temperatures vaporizing a portion of the water as it trickled from the jackets, and while it was filling the tank.

Line 10 gives the total number of pounds of steam which passed through the cylinder during the experiments. This quantity was obtained by deducting the quantities on line 9 from those on line 8.

Line 11 gives the total number of cubic feet of water which flowed from the hot-well into the tanks, where it was carefully measured. This quantity is the sum of the feed-water pumped into the boilers, and of the injection-water admitted to the condenser.

Line 12 gives the weight of this water in pounds, obtained by multiplying the quantities on line 11 by the weights, respectively, of a cubic foot of water at the temperature on line 23. These quantities are, necessarily, too small, by the quantities vaporized under the atmospheric pressure from the open surface of the water in the tanks.

Line 13 contains the total number of double strokes made by the steam piston during the experiments, or of revolutions made by the crank-shaft of the engine.

Engine.—Lines 14 to 19, both inclusive, show the principal conditions under which the engine was operated during the experiments.

Line 14 gives the steam-pressure in the boiler, and line 15 gives it in the steam-pipe near the cylinder, in pounds per square inch above the atmosphere.

Line 16 gives the proportion of throttle-valve open; as there was no throttle-valve, the opening was "wide."

Line 17 gives the fraction of the stroke of the piston completed when the steam was cut off, as obtained in each experiment from the representative indicator diagram furnished with Mr. Fletcher's report. The point of cutting off was assumed to be where the convex throttled curve reversed into the concave expansion curve of the diagram.

Line 18 gives the number of times the steam was expanded for each experiment, and includes the effect of the space in the cylinder clearance and steam-passage.

Line 19 gives the mean number of double strokes made by the steam-piston per minute.

Temperatures.—Lines 20 to 24 contain mean temperatures in Fahrenheit degrees.

Line 20 gives the temperature of the feed-water in the tank when it was measured; and line 21 gives its temperature when it entered the boiler.

The quantities on line 21 show the temperature of the feed-water when it entered the boiler.

Line 22 gives the temperature of the injection water.

Line 23 gives the temperature of the water on entering the tanks from the hot-well. These tanks were 8 feet from the air-pump.

All the above temperatures were taken by common mercurial thermometers; but the temperature of the gases of combustion emerging from the experimental boilers, was taken by a metallic pyrometer, and is given on line 24.

Rate of Combustion.—The number of pounds of coal consumed per hour, and per hour per square foot of the grate- and heating-surfaces of the boiler, are given on lines 25, 26 and 27, respectively.

Steam-Pressures in Cylinder, per Indicator.—Lines 28 to 33, both inclusive, contain the mean steam-pressures in the cylinder, as given by the indicator diagrams.

Line 28 gives the pressure of the steam on the piston at the beginning of its stroke; and line 29 gives that pressure at the end of its stroke—in both cases, in pounds per square inch above zero.

Line 30 gives the indicated pressure on the piston, in pounds per square inch; and line 31 gives the back pressure of the uncondensed steam against the piston in pounds per square inch. This latter quantity is taken from the representative diagram given for each experiment in Mr. Fletcher's report.

Line 32 gives the net pressure on the piston in pounds per square inch. It is the indicated pressure on line 30, less 2 pounds per square inch, assumed for the pressure per square inch of piston to work the engine, *per se*, or the unloaded engine.

Line 33 gives the total pressure on the piston in pounds per square inch. It is the indicated pressure on line 30, plus the back pressure on line 31.

Horse-Powers.—Lines 34, 35 and 36 contain, respectively, the mean indicated, net and total horse-powers developed by the engine during the experiments, and are calculated for the pressures on lines 31, 32 and 33.

Line 37 gives the total horse-powers developed by the expanded steam after the closing of the cut-off valve, obtained, as nearly as possible, from the representative indicator diagrams above referred to. These quantities are only of use in computing those on lines 48, 58 and 59.

Economic Results.—Lines 38 to 46, both inclusive, give the economic results obtained from the machinery under the experimental conditions.

Lines 38, 39 and 40 show, respectively, the cost of the indicated, net and total horse-powers in pounds of coal consumed per hour. The quantities on these lines are the quotients of the division of the quantities on line 25, by those on lines 34, 35 and 36. It must not be overlooked that these results are not properly comparable in the different experiments, because they are from different kinds of boiler, different kinds of coal, different rates of combustion, and different temperatures of feed-water.

Lines 41, 42 and 43 show, respectively, the cost of the indicated, net and total horse-powers in pounds of feed-water consumed per hour. The quantities on these lines are the quotients of the division of the quantities on line 8, by those on line 4, and by those on lines 34, 35 and 36; and these quotients would be strictly comparable for the different experiments, were the units of heat in a pound of steam the same at all pressures. But as they vary, it is necessary to substitute the number of units of heat consumed per hour per horse-power for the pounds of steam; and this has been done on lines 44, 45 and 46, whose quantities were obtained by multiplying those on lines 41, 42 and 43 by the number of Fahrenheit units in a pound of steam of the pressure on line 14, with a uniform temperature for the feed-water of 100° Fahrenheit.

Condensation in Cylinder.—Lines 47 to 51, both inclusive, contain the quantities necessary for ascertaining the condensation undergone by the steam in the cylinder, independent of the condensation therein effected by the transmutation of heat into the power on line 37 developed by the expanded steam, or after the closing of the cut-off valve.

Line 47 gives the number of pounds of steam discharged, during the experiments, from the cylinder into the condenser, calculated from the weight of a cubic foot of steam of the pressure at the end of the stroke of the piston on line 29, from the number of double strokes of piston on line 13, and from the number of cubic feet of piston displacement per stroke plus the space in the cylinder clearance and steam-passage at one end, allowing deductively for the weight of steam already present in that space when the piston begins its stroke.

Line 48 contains the number of pounds of steam condensed in the cylinder, during the experiments, to produce the power on line 37, which power is developed by the expanding steam only, and is additional to the power developed by the non-expanded steam previous to the closing of the cut-off valve, the sum of the two forming the total horses-power developed by the engine, that is, the quantities on line 36.

Line 49 gives the number of pounds of water of condensation withdrawn, during the experiments, from the steam-jackets of the cylinder; these quantities are the same as those on line 9.

Line 50 contains the sum of the quantities on lines 47, 48 and 49, and, were there no cylinder condensation other than that due to the development of the power on line 37, this sum would exactly equal the weight of feed-water pumped into the boiler as given on line 8. Under no circumstances can it be greater, and by whatever quantity it is less, that quantity is the weight of steam condensed in the cylinder by all causes other than the production of the power above referred to.

Line 51 contains this less quantity for the different experiments, expressed in per centum of the weight of feed-water pumped into the boiler.

Vaporization.—Lines 52 to 55, both inclusive, give the vaporizations, during the experiments, that would have been, had the feed-water been pumped into the boilers at the temperatures of 100° and 212° Fahrenheit, and vaporized under the standard atmospheric pressure of 29·92 inches of mercury. These equalizations are necessary in order to determine the relative economic efficiencies of the boilers, and of the coal at the different rates of combustion.

Line 52 contains what would have been the vaporization from the temperature of 100° Fahrenheit; and line 53 contains what would have been the vaporization from the temperature of 212° Fahrenheit.

Line 54 contains the quotients of the division of the quantities on line 52 by those on line 6; and line 55 similarly contains the quotients of the division of the quantities on line 53 by those on line 6. These quotients show the number of pounds of water vaporized by 1 pound of coal, from the temperatures of 100° and 212° Fahrenheit, and under the standard atmospheric pressure in the respective boilers, and with the experimental rates of combustion.

Comparison of the Heat imparted to the Steam in the Boiler, and accounted for in the Hot-Well.—Lines 56 to 62, both inclusive, contain the quantities necessary for comparing the amounts of heat imparted to the steam in the boiler and in the condenser, above the temperature of the hot-well, with the amounts accounted for in the condensing water above the temperature of the injection and by the production of the total horse-powers developed by the expanded steam after the closing of the cut-off valve.

[To be continued.]

Movement of Tempests.—M. Faye has studied tempests as moving whirlpools with vertical axes, comparing them to the eddies of streams. In the course of a river, as soon as there is any difference of velocity between contiguous portions of water, such eddies tend to be produced. As soon as the tendency becomes effective, it can be mathematically shown that the angular velocity of rotation increases in the inverse ratio of the square of the distance from the axis. Moreover, although the eddy is plunged in the mass of the surrounding water, it will remain isolated, as it were, by a surface of its own, which is a surface of revolution around the vertical axis, with the concavity of its meridian generatrix turned downward.—*Comptes Rendus.* C.

ECONOMIC VAPORIZATION OF WATER AND EXPANSION OF STEAM.

By Chief Engineer ISHERWOOD, U. S. Navy.

Table containing the Data and Results of the Experiments made by Mr. LAVINGTON E. FLETCHER at Dalkeith, Scotland, on the Engine and Boilers of the Paper Mill belonging to Robert Craig & Sons, determining, for the experimental conditions, the Economic Vaporization of each of the two kinds of Boiler experimented with, and of the two kinds of Coal consumed; also, the Relative Economic Efficiency of the Different Measures of Expansion with which the Steam was used, and of the Steam-Jacket around the Cylinder.

No. of Line.			STEAM IN CYLINDER JACKET.			NO STEAM IN CYLINDER JACKET.	
			A	B	C	D	E
1		Date of Experiment,	February 7, 1877.	February 8, 1877.	February 12, 1877.	February 9, 1877.	February 10, 1877.
2	BOILER.	Square feet of grate surface in use,	39·5	39·5	36·6	36·6	39·5
3		Square feet of heating surface in use,	1420·0	1420·0	698·5	698·5	1420·0
4	TOTAL QUANTITIES.	Duration of experiment, in consecutive hours,	6·	7·	4½·	7·	7·
5		Kind of coal consumed,	Scotch.	Welsh.	Scotch.	Scotch.	Scotch.
6		Total number of pounds of coal consumed,	3136·	2954·	3752·	5936·	4592·
7		Total number of cubic feet of feed-water pumped into the boiler,	456·00	505·33	352	551·33	531·33
8		Total number of pounds of feed-water pumped into the boiler,	28359·3254	31413·2669	21873·1262	34288·1097	33003·3626
9		Total number of pounds of water of condensation withdrawn from cylinder jacket,	936·0000	1092·0000	702·0000	———	———
10		Total number of pounds of water passing through the cylinder as steam,	27423·3254	30321·2669	21171·1262	34288·1097	33003·3626
11		Total number of cubic feet of condensing-water and feed-water measured in hot-well,	7060·	7980·	6700·	9040·	8430·
12		Total number of pounds of condensing-water and feed-water measured in hot-well,	437861·2565	494367·1606	416038·7311	559802·9492	521794·2643
13		Total number of double strokes made by the steam-piston,	19296·	22176·	13446·	22050·	22050·
14	ENGINE.	Steam pressure in boiler, in pounds per square inch above atmosphere,	57·5	57·5	32·5	37·5	32·5
15		Steam pressure in steam-pipe near cylinder, in pounds per square inch above atmosphere,	53·3	52·3	31·0	34·7	31·8
16		Proportion of throttle-valve open,	Wide.	Wide.	Wide.	Wide.	Wide.
17		Fraction of the stroke of the piston completed when the steam was cut off,	0·120	0·173	0·500	0·380	0·346
18		Number of times the steam was expanded,	5·710	4·448	1·882	2·3876	2·5842
19		Number of double strokes made per minute by the steam-piston,	53·6	52·8	49·8	52·5	52·5
20	TEMPERATURES	Temperature, in degrees Fahrenheit, of the feed-water in the tank,	90·59	83·65	85·22	80·60	88·80
21		Temperature, in degrees Fahrenheit, of the feed-water when pumped into the boiler,	223·00	183·84	85·22	80·60	88·80
22		Temperature, in degrees Fahrenheit, of the injection water,	41·00	41·00	41·50	41·00	44·00
23		Temperature, in degrees Fahrenheit, of the hot-well,	96·43	102·58	90·90	104 67	106·80
24		Temperature, in degrees Fahrenheit, of the gases of combustion in the chimney,	400·00.	400·00	over 800·00	over 800·00	450·00
25	RATE OF COMBUSTION.	Pounds of coal consumed per hour,	522 6667	422·0000	833·7778	848·0000	656·0000
26		Pounds of coal consumed per hour per square foot of grate surface,	13·2321	10·6835	22·7808	23·1694	16·6076
27		Pounds of coal consumed per hour per square foot of heating surface,	0·3680	0·2972	1·1937	1·2112	0·4620
28	STEAM PRESSURES IN CYLINDER PER INDICATOR.	Steam pressure in cylinder, in pounds per square inch above zero, at beginning of stroke of piston,	58·97	58·02	41·48	41·88	39·78
29		Steam pressure in cylinder, in pounds per square inch above zero, at end of stroke of piston,	11·84	13·00	14·14	14·00	12·52
30		Mean indicated steam pressure on pistons, in pounds per square inch,	23·50	24·72	23·64	22·28	20·82
31		Mean back pressure against piston, in pounds per square inch,	3·00	2·50	3·00	3·75	2·50
32		Mean net pressure on piston, in pounds per square inch,	21·50	22·72	21·64	20·28	18·82
33		Mean total pressure on piston, in pounds per square inch,	26·50	27·22	26·64	26·03	23·32
34	HORSES-POWER.	Indicated horses-power developed by the engine,	187·669	194·465	175·403	174·275	162·855
35		Net horses-power developed by the engine,	171·697	178·732	150·563	158·631	147·411
36		Total horses-power developed by the engine,	211·627	214·132	197·662	203·607	182·410
37		Total horses-power developed by the expanded steam after the closing of the cut-off valve,	155·7	136 6	53·0	85·3	80·1
38	ECONOMIC RESULTS	Pounds of coal consumed per hour per indicated horse-power,	2·7850	2·1700	4·7535	4 8659	4 0281
39		Pounds of coal consumed per hour per net horse-power,	3·0441	2·3611	5·5377	5·3458	4·4501
40		Pounds of coal consumed per hour per total horse-power,	2·4698	1·9707	4·3053	4·1649	3·5963
41		Pounds of feed-water consumed per hour per indicated horse-power,	25·1856	23·0767	27·7116	28·1067	28·9507
42		Pounds of feed-water consumed per hour per net horse-power,	27·5285	25·1080	32·2835	30 8786	31·9838
43		Pounds of feed-water consumed per hour per total horse-power,	22·3344	20·9572	24·5909	24·0576	25·8471
44		Fahrenheit units of heat consumed per hour per indicated horse-power,	27878·3990	25544·0195	30441·3007	30929·8185	31802·2569
45		Fahrenheit units of heat consumed per hour per net horse-power,	30471·8277	27792·5022	35463·5487	33980·1361	35134·3290
46		Fahrenheit units of heat consumed per hour per total horse-power,	24722·3538	23197·9061	27011·1996	26474·0151	28395·3372
47	CONDENSATION IN CYLINDER.	Pounds weight of steam discharged from the cylinder into the condenser, calculated from the pressure at the end of the stroke of the piston,	20740·6865	26178·3459	17264·6826	28032·4042	25066·2765
48		Pounds weight of steam condensed in the cylinder to produce the power developed by the expanded steam after the closing of the cut-off valve,	2605·9558	2667·3249	650·9295	1599·3748	1530·2987
49		Pounds of water withdrawn from the jacket of the cylinder,	926·0000	1092·0000	702·0000	———	———
50		Sum of the above three quantities,	24272·6423	29937·6708	18617·6121	29631·7790	26596·5752
51		Difference between the weight of water pumped into the boiler, and the immediately above quantity, in per centum of the former, being the per centum of the steam evaporated in the boiler, condensed in the cylinder,	14·4104	4·6974	14·8836	13·5800	19·4125
52	VAPORIZATION.	Pounds of water that would have been vaporized in the boiler, had it been supplied at the temperature of 100 degrees Fahrenheit and vaporized under the pressure of 29·92 inches of mercury,	25820·9709	29708·1452	22577·1841	35609·8146	33955·9335
53		Pounds of water that would have been vaporized in the boiler, had it been supplied at the temperature of 212 degrees Fahrenheit and vaporized under the pressure of 29·92 inches of mercury,	28837·9094	33261·1360	25215·1165	39760·1327	37923·3653
54		Pounds of water vaporized from 100 degrees Fahrenheit by one pound of coal,	8·2337	10 0569	6·0174	6·9990	7·3946
55		Pounds of water vaporized from 212 degrees Fahrenheit by one pound of coal,	9·1958	11·2597	6·7204	6·6981	8·2586
56	HEAT IMPARTED TO THE STEAM IN THE BOILER AND ACCOUNTED FOR IN THE HOT-WELL	Number of Fahrenheit units of heat imparted to the steam in the boiler above the temperature of the water in the hot-well,	28370321·3844	31181375·1175	21852889·6082	34981137·5444	33540066·5829
57		Number of Fahrenheit units of heat added to the steam in the condenser,	1514609·8326	1686142·0400	1244683·7420	1983153·6167	1910578·6672
58		Number of Fahrenheit units of heat taken from the water of condensation due to the production of the power,	387571·6750	407432·4632	103444·9382	258568·3235	231554·2053
59		Number of Fahrenheit units of heat equivalent to the total horses-power developed by the expanded steam, or after the closing of the cut-off valve,	2343637·6480	2398829·2861	698327·5306	1497951·2306	1406634·1568
60		Number of Fahrenheit units of heat which should have been found in the condensing-water above its temperature when injected, being the difference of the quantity on line 59 and the sum of the quantities on lines 56, 57 and 58,	27928865·2440	30876120·3346	22602690·7528	35724908·2540	34275565·2886
61		Number of Fahrenheit units of heat in the condensing-water above its temperature when injected,	22774232·1632	28610102·6961	19524323 4925	33501368·1694	30737932·5899
62		Difference between the number of Fahrenheit units of heat which should have been found in the condensing-water above its temperature when injected, and the number that were found, in per centum of the latter; being the per centum of heat lost by steam and water leakage from boiler and engine, by difference of evaporation into the atmosphere from the surface of the water in the tanks for measuring the feed-water and the hot-well water, by external radiation from the surfaces of the exhaust pipe, condenser, air-pump and hot-well, and due to errors of observation,	22·6336	7·9203	16·7668	6·6372	11·509

MEMOIRS ON THE LIQUEFACTION OF OXYGEN, THE LIQUEFACTION AND SOLIDIFICATION OF HYDROGEN, AND ON THE THEORIES OF THE CHANGES IN CONDITION OF BODIES.

By R. Pictet.

Translated for the Journal of the Franklin Institute, by P. Pistor, M. E.

[Continued from Vol. lxxvi, page 111.]

IV.—Calculation of the Density of Liquid Oxygen.

MAXIMUM TENSIONS.

If we discuss the results of the experiments related in the preceding chapter, we can deduce several consequent conclusions on the physical properties of liquefied oxygen.

In order to do so, let us first calculate the weight of oxygen liberated during the reaction. We have the formula:

$$2\ KCl.\ O^3 = KCl + O^6.$$

Applying it to 700 gr. of chlorate of potassa, we have

$$700 \times 39{\cdot}16 = 274{\cdot}12 \text{ grammes.}$$

To obtain the volume of this mass of gas at 0°, the weight should be divided by the sp. gr., δ; $\delta = 1{\cdot}437$ (Regnault); and we get

$$\frac{274{\cdot}12}{1{\cdot}437} = 191{\cdot}4 \text{ litres.}$$

These 191·4 litres have been heated to 485°, and fill a volume composed of two parts.

1. The empty space above the chloride of potassium.
2. The volume of tube A, from the flask to the manometer.

Let us designate the first by v, the second by v'.

Imagine v and v' to be at the same temperature of 485°, and calculate the final pressure that should be due to the liberation of 191·4 litres of oxygen.

The law of Mariotte and Gay-Lussac supposed to be correct, we have

$$(1.)\qquad P = \frac{191{\cdot}4\ (274 + 485)\ 1000}{274 \times (v + v')}.$$

v and v' are expressed in cubic centimetres.

The weight of the water necessary to fill the flask after the experiments gives

$$v = 944 \text{ cubic centimetres exactly.}$$

As to v', it is equal to the cross-section of the tube multiplied by its total length. The tube is 4 mm. in diameter and 4·16 m. in length, therefore

$$v' = \pi \,.\, 0{\cdot}2^2 \times 4{\cdot}16 \text{ m.} = 52{\cdot}25 \text{ cubic centimetres.}$$

Substituting for v and v', in equation (1), their values, we find the value of P. The temperature, 485°, which acts on the volume, v, is duly considered if we take as a coefficient of the expansion of iron,

$$k = 0{\cdot}0000122045,$$

and we get the final formula,

$$(2.) \qquad P = \frac{191{\cdot}4\,(274 + 485)\,1000}{274\,[944\,(1 + 485 \times 3 \times 0{\cdot}0000122045) + 52{\cdot}25]}\,.$$

$$P = 532{\cdot}10 \text{ atmospheres.}$$

We see, from the above, that the pressure corresponding to the production of 191·4 litres of oxygen is a maximum of 532·10 atmospheres. This pressure was not reached, but was closely approached; we saw the manometer at 522, 524, 517 atmospheres, but never exceeding 526 (third experiment).

The pressure, on the contrary, after having rapidly fallen, remained stationary during several minutes. This stoppage in the movement of the hand of the manometer, is an evident indication that the condensation had also come to a standstill. What can be the cause?

But one is admissible: it is, that the condensing tube is full of liquid. If it were not, condensation would infallibly continue, as the temperature is kept constant by the action of more than two kilogrammes of solid carbonic acid, or of protoxide of nitrogen.

It is therefore necessary to know exactly, the volume of that part of the tube where condensation can take place.

Between the manometer m', and the upper end of the tube containing carbonic acid, I find a distance of exactly 3·62 m. The volume v (wherein the oxygen liquefies) is therefore

$$(3.) \qquad v = \pi\, \overline{0{\cdot}2^2} \times 3{\cdot}62 \text{ m.} = 45{\cdot}467 \text{ cubic centimetres.}$$

The temperature of this tube is about — 120° and tends to diminish its volume; on the other hand, it is subjected to a very considerable pressure on the inside, which tends to increase its volume. Both these causes produce but small results, numerically speaking, and opposed to one another. Without any great error, we can therefore use the value as it is.

Let us calculate, for each experiment, the difference between the theoretical pressure which should be attained without condensation, and the "stationary pressure" obtained before the first jet. We would then have an estimate of the variation in volume, corresponding to the change of condition produced.

	1.	2.	3.	4.	5.
Theoretical pressure,	532·10	532·10	532·10	532·10	532·10
Observed "	470·	471·	471·	469·	469·
Differences,	62·10	61·10	61·10	63·10	63·10

The mean of these five experiments gives 62·1 atmospheres as the difference.

The weight in grammes, represented by a variation of 1 atmosphere can be calculated. Let us designate it by p. We have the formula:

$$(4.)\qquad p = \frac{274{\cdot}12}{532{\cdot}10}\text{ grammes} = 0{\cdot}51517\text{ gr.}$$

Therefore the weight F of the liquefied oxygen is equal to

$$(5.)\qquad F = \frac{274{\cdot}12}{532{\cdot}10} \times 62{\cdot}10 + \left\{\begin{array}{l}\text{The weight of the gas contained}\\ \text{in the tube before liquefaction.}\end{array}\right.$$

When calculating the maximum theoretical pressure, we have supposed the whole volume $v + v'$ occupied by the gas, to be at a temperature of + 485°. We should therefore calculate the weight of compressed gas in the volume v' at 485°. This weight is determined by the proportion.

$$(6.)\qquad 996{\cdot}25 : 274{\cdot}12 : : 45{\cdot}467 : x,$$

from which x may be found

$$x = 12{\cdot}51\text{ grammes.}$$

The variation of pressure observed before the first jet, indicates the variation of volume corresponding to the change of condition; the weight of condensed gas is therefore: "the sum of the weight of gas in the tube before condensation, plus the weight of gas represented by the diminution of pressure." Calling this weight R, its value is

$$(7.)\qquad R = 12{\cdot}51 + 62{\cdot}1 \times 0{\cdot}51517\text{ grammes.}$$

$$R = 44{\cdot}502\text{ grammes.}$$

The volume occupied by this liquid is equal to v', therefore,

$$(8.) \qquad \frac{R}{v'} = \text{the density of liquid oxygen } d,$$

consequently

$$\frac{44{\cdot}502}{45{\cdot}467} = d = 0{\cdot}9787.$$

This is therefore the density of liquid oxygen, deduced from direct observations made during the five experiments, with this object in view.

M. Dumas, perpetual secretary of the Academy of Sciences at Paris, wrote to us the following remarks on the 26th of last December.

"Allow me to add that, if I am not mistaken, the density of liquid oxygen must be equal to that of water.

"The density of sulphur being 2, what I called its atomic volume, about 60 years ago at Geneva, itself would be equal to $\frac{32}{2} = 16$.

"The isomorphous bodies having the same atomic volume, that of oxygen taken as 16, would give $\frac{16}{16} = 1$ for the density of solid oxygen, and almost this figure for the liquid state.

"The atomic volume of phosphorous being 15·5, we would have for nitrogen $\frac{14}{15{\cdot}5} = 0{\cdot}9$, and more probably 0·45, on account of the doubled state of its molecule.

"The atomic volume of magnesium being 13·8, that of hydrogen would be $\frac{1}{13{\cdot}8} = 0{\cdot}07$, at least.

"This volume might be much higher, if hydrogen, like potassium and sodium, presented, in a disengaged state, a much larger volume than that assumed in a combined state.

"These surmises may be of some value in explaining the probable condition of the liquid you should obtain. It would be very interesting to know whether the density of liquid oxygen approaches or recedes from that, one is inclined to attribute to it.

"But the problem of molecular mechanics, whose solution you seek, claims you entirely, and I would reproach myself did I divert you from it; notwithstanding the paternal interest I take in the determination of the atomic volume.

"P. S.—If hydrogen is a metal, as I have allowed myself to think since my youth, would not its condensation produce a solid amalgam, by compressing it on congealed mercury?

"In this case, the tension might be destroyed or diminished."

We are very happy to have been able, experimentally, to confirm the predictions of the illustrious chemist; and we think that this verification, obtained sixty years after the foundation of the atomic theory, is a grand triumph for its most ardent and learned advocate.

Second Method.—The experiments whose essential results we have given, will allow a second estimate of the density. A less accurate estimate than that we obtained from the preceding calculations, but which, nevertheless, should not be despised. We conduct this second investigation in the following manner: the regulating cock was closed after the first jet of liquid oxygen, at the well defined moment when the liquid jet was replaced by a gaseous jet. The thick mist produced by the vesicular condition of condensed oxygen at the moment of expansion will not interfere in the least with its determination, and may be observed simultaneously by several assistants. It may therefore be asserted that all the condensed liquid has escaped through the orifice, at the moment of closing the screw plug-cock. The tube must be full of gas under pressure.

This gas comes from a flask whose temperature is very high, and enters the thoroughly chilled tube. The probable temperature of the gas should be estimated at the instant of closing the plug-cock.

It is known that gases assume the temperature of the envelope containing them with extraordinary facility, especially if the spaces are restricted. We can, therefore, infer the temperature of the gas from the differences in temperature taking place in the gas which cools, and in the copper of the tube which becomes heated.

The weights of these bodies are known, also their specific heats, and their extremes of temperature: the solution is, therefore, possible.

Let us calculate the weight, A, of the copper tube. Its dimensions are:

Exterior diameter = . . . 15 mm.
Interior " = . . . 4 "
Length = ... 3 62 m.
Density = ... 8·95.

We have:

$$A = \pi\,(\overline{0\ 75}^2 - \overline{0\ 2}^2)\ 362 \times 8{\cdot}95 \text{ grammes.}$$
$$A = 5319\ 3 \text{ grammes.}$$

At the end of the first jet, after the condensation of the oxygen and its expulsion, the maximum temperature of the copper may be estimated at — 110° as the highest limit.

Let us designate by x the number of degrees to which the temperature of the copper will be raised, and, by y, the corresponding number of degrees the temperature of F grammes of gas, contained in the tube, under pressure P, will be lowered.

We can form the two equations:

(9.) $5{\cdot}3193 \times c \times x = F \times k \times y.$

(10.) $x + y = 485 - (-110) = 595.$

In these equations,

$c =$ specific heat of copper, 0·094, and

$k =$ specific heat of the oxygen at a constant pressure $= 0{\cdot}2182$.

As for F, it is given by the formula:

(11.) $$F = \frac{0{\cdot}045467 \times 1{\cdot}437\,(274 + x - 110) \times \text{press. in atm.}}{274}.$$

Solving these equations, we find, as numerical results:

$x = 4$ degrees.

$y = 591$ degrees.

$F = 16{\cdot}59$ grammes for $P = 400$ atmospheres.

For each of the five experiments made, we will add the weight of oxygen corresponding to the diminution of pressure, observed at the moment of its again becoming stationary, to the weight of gas contained in the tube. The sum will represent the weight of liquid oxygen before the second jet issues.

First Experiment.—The initial pressure is 367 atmospheres. Formula (11) applied, gives for F:

$$F = \frac{0{\cdot}045467 \times 1{\cdot}437 \times 168 \times 367}{274} = 14{\cdot}705 \text{ grammes.}$$

On the other hand, we know that the pressure has gradually diminished from 367 to a stationary one of 308. The difference is 59 atmospheres.

The weight corresponding to this difference is

$$F = 0{\cdot}51517 \times 59 = 30{\cdot}395 \text{ grammes.}$$

The sum $F + F' =$ the weight of condensed oxygen.

$$F + F' = 45{\cdot}100 \text{ grammes.}$$

This experiment would give a value as the density of liquid oxygen:

$$\frac{45{\cdot}100}{45{\cdot}467} = 0{\cdot}9919.$$

Second Experiment.—The initial pressure is 395 atmospheres,

$$F = 16{\cdot}21 \text{ grammes.}$$

The pressure descends gradually from 395 to 339 atmospheres, where it remains stationary. This is a difference of 56 atmospheres.

$$F' = 0{\cdot}51517 \times 56 = 28{\cdot}85.$$

$$F + F' = 45{\cdot}06 \text{ grammes.}$$

The density $\frac{45{\cdot}06}{45{\cdot}467} = 0{\cdot}9908$.

Third Experiment.—The initial pressure is 432 atmospheres,

$$F = 17{\cdot}306 \text{ grammes.}$$

The pressure falls to 378 atmospheres. The difference is 54 atmospheres.

$$F' = 54 \times 0{\cdot}51517 = 27{\cdot}82 \text{ grammes.}$$

$$F + F' = 45{\cdot}126 \text{ grammes.}$$

The density $\frac{45{\cdot}126}{45{\cdot}467} = 0{\cdot}9925$

Fourth Experiment.—The initial pressure is 400 atmospheres,

$$F = 16{:}59 \text{ grammes.}$$

The pressure falls to 346 atmospheres. The difference is 54 atmospheres.

$$F' = 54 \times 0{\cdot}51517 = 27\ 82 \text{ grammes.}$$

$$F + F' = 44{\cdot}41 \text{ grammes.}$$

The density $\frac{44{\cdot}41}{45{\cdot}467} = 0{\cdot}9767$.

Fifth Experiment.—The initial pressure is 416 atmospheres,

$$F = 16{\cdot}665 \text{ grammes.}$$

The pressure descends to 361 atmospheres, difference 55 atmospheres.

$$F' = 55 \times 0{\cdot}51517 = 28\ 33 \text{ grammes.}$$

$$F + F' = 44{\cdot}995 \text{ grammes.}$$

The density $\frac{44\ 995}{45{\cdot}467}\ 0{\cdot}9896$.

Taking a mean of the five experiments we will get a more exact result; and we find for the density

$$d = 0{\cdot}9883.$$

The first method we adopted gave us the value

$$d = 0\ 9787.$$

The difference 0·0096 may be classed with errors of observation. In fact, our manometer can only record pressures with accuracy to within 1 atmosphere, and we have been obliged to use the specific heats beyond the limits of their experimental determination. The lowering of temperature during the experiments is a permanent cause of error, which tends to exaggerate the density.

Although having given the mean value of the density, deduced from the variations in pressure following the first jet during five experiments, we still think that the first method is more reliable, and furnishes a result that approaches nearer to reality. The number 0 9787, therefore, seems to us the most exact.

Maximum Tension of the Vapors of Oxygen.—The second physical element we intend to determine with exactitude, by means of the five recorded experiments, is the maximum tension of the vapors of oxygen. This determination is still very incomplete, as it demands a far greater number of experiments. It will be necessary to be able to cause the temperatures to vary between certain well-defined limits, and to observe the corresponding changes in pressure.

Our aim having been, principally, to liquefy the oxygen, we have utilized the minimum temperature attainable with our means. We made use of either carbonic acid, or protoxide of nitrogen, as an auxiliary liquid, and obtained, in consequence, two minima, one corresponding to each of the two liquids.

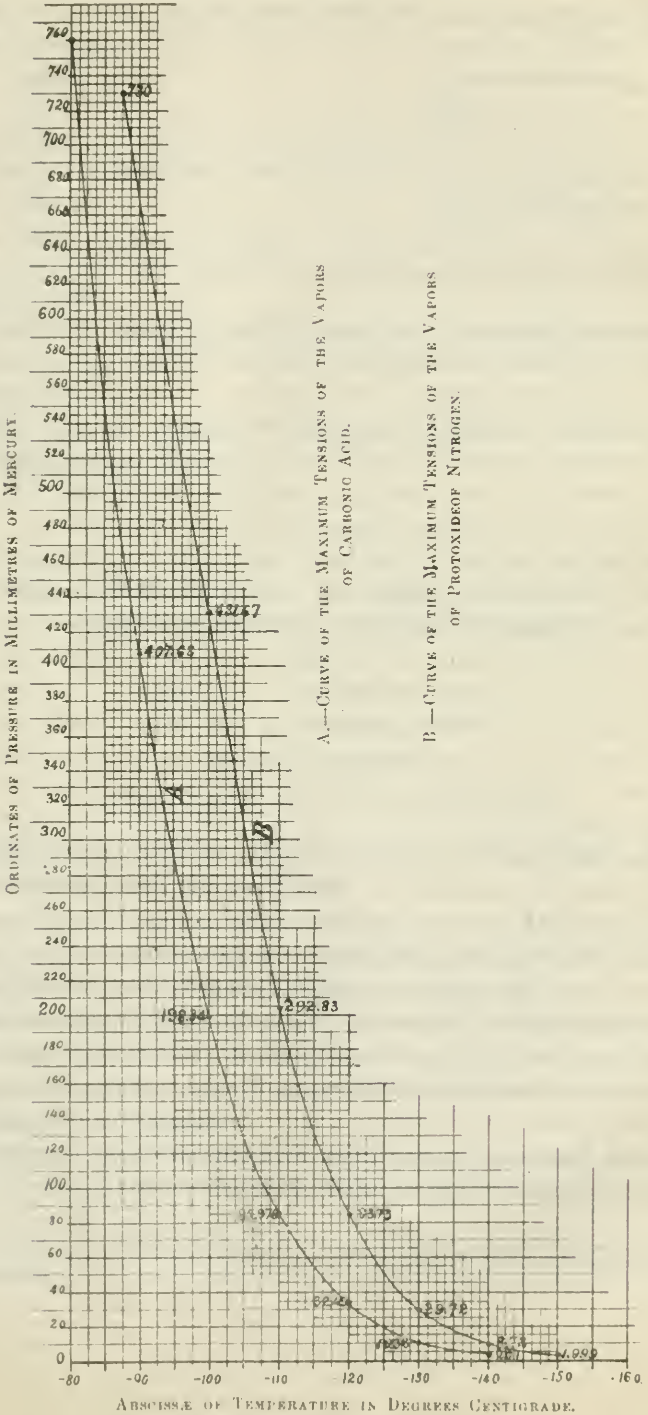
The numerical results contained in the table,[1] clearly show us the value of these two minima; one corresponding to the temperature of solid carbonic acid; the other, to that of the protoxide of nitrogen.

After the second liquid jet, during the first experiment, the pressure is still 285 atmospheres. This pressure falls gradually to the lower limit, 274, where it remains stationary and invariable during several minutes. This fall corresponds to a diminution of only 11 atmospheres. The weight of oxygen liquefied during the fall does not exceed 6 grammes. We are, consequently, certain that the condenser tube "is not full." Therefore, were the tension of the vapors of oxygen corresponding to the temperature of solid carbonic acid, less than 274 atmospheres, "condensation must continue;" but we see that it is arrested, consequently the maximum tension of the vapors of oxygen at this temperature is exactly 274 atmospheres.

---

[1] See page 111 ant., at the end of last chapter.

PICTET'S EXPERIMENTS OF DECEMBER 22d, 1877. PLATE II.



The first three experiments, made with carbonic acid, give us the following results:

1st, ...	274 atmospheres.
2d, ...	271 “
3d, ...	272 “

The last two experiments, made with protoxide of nitrogen, give:

4th, ...	251 atmospheres.
5th, ...	253 “

The pressure is less with the protoxide of nitrogen than with the carbonic acid.

In order to attach a precise significance to these figures, the temperature, in degrees, to which these pressures correspond, must be accurately known.

Below are the successive deductions which have enabled us to obtain a first approximation

(To be continued.)

ON THE DEVELOPMENT OF THE CHEMICAL ARTS, DURING THE LAST TEN YEARS.[1]

By Dr. A. W. Hofmann.

From the *Chemical News.*

[Continued from Vol. lxxvi, page 129.]

Phosphorus and Matches. By Dr. Anton von Schrötter, Master of the Imperial Mint at Vienna.

Few substances are so calculated to excite our interest from every point of view so decidedly as phosphorus. Its relations especially to the organic world claim especially our whole attention.

This element, discovered nearly two centuries ago by Brand and afterwards described by Kunkel, has been therefore the subject of many investigations, and yet many of its properties are even yet not satisfactorily understood.

Phosphorus was first obtained from human urine, and a hundred years afterwards it was shown by Gahn to be an essential constituent of bones. From this fact its universal diffusion in nature might have been inferred, but it has been only of late demonstrated that not merely most substances found on the earth's surface contain phosphorus, but that it is present in most springs, in all rivers, in the sea, and even in the atmosphere (Barral), although but in slight traces. In fact, upon a soil free from compounds of phosphorus no plant could grow. In this respect, therefore, phosphorus ranks among the elements necessary for building up the vegetable and animal body, like oxygen, nitrogen, carbon, hydrogen, chlorine, sulphur, iron, calcium, etc.

---

[1] “Berichte über die Entwickelung der Chemischen Industrie während des letzten Jahrzehends.”

Let us now, as far as our immediate purpose allows, consider the properties of phosphorus more closely.

The only kind of phosphorus which was known up to 1848, and which exclusively occurred in trade, and is still known as "ordinary," is a yellow translucent, and, when recently prepared and preserved from the action of light, perfectly limpid body, brittle at low temperatures, but assuming at 15° C. the consistence of wax. Notwithstanding this cerous consistence it still possesses a perfectly crystalline texture, as may be readily perceived by exposure for some time to the action of dilute nitric acid, which attacks it slightly, leaving a surface like that exhibited by tin after treatment with a dilute acid. The single crystals obtained from solvents are decidedly octahedra, exactly agreeing in appearance with common phosphorus, which may therefore justly be called the octahedral. Mitscherlich, however, has observed phosphorus crystallized in dodecahedra.

On exposure to a moist atmosphere phosphorus is luminous in the dark in consequence of a very gradual oxidation and formation of phosphorous acid, which gradually passes into the phosphoric. At the same time a small part of the uncombined oxygen is converted into the modification known as ozone.

The phosphoric vapors hereby diffused exert a very poisonous action if inhaled, producing a disease known as phosphorus necrosis, which begins with the disintegration of the jaw-bones and ends with their total destruction, and under which ill-fed and scrofulous persons sink with peculiar rapidity. Phosphorus introduced into the stomach acts as a violent poison.

With regard to its chemical behavior phosphorus must be placed in the same group of elements as nitrogen, arsenic, antimony, and perhaps some other of the simple bodies.

If preserved under water and exposed to daylight, ordinary phosphorus is covered with a white crust which gradually becomes detached. The nature of this body was for a long time doubtful. Baudrimont,[i] however, has shown that this crust is formed only under access of oxygen, and possesses all the attributes of ordinary phosphorus, whence we can scarcely doubt that it is merely common phosphorus which, assisted by the presence of the water, crumbles away from the sticks corroded by oxygen.

We may here also refer to the long-known, so-called black phosphorus, which, according to Thénard, may be obtained by rapidly cooling phosphorus—previously often distilled—an operation which, be it remarked, has never succeeded in the hands of the writer of this report. According to Blondlot[ii] phosphorus also becomes black when cooled slowly, but it must be perfectly pure and limpid. The black color is said to depend upon a black body, very minute traces of which are mixed with common phosphorus, which is left behind on solution in carbon bisulphide and passes over first on distillation, so that the last drops are colorless. Black phosphorus is rather softer than the ordinary kind, but is otherwise scarcely distinguishable. The nature of the black substance accompanying ordinary phosphorus, the formation of which is said to be promoted by mercury, though the latter element forms no part of its composition, is as yet unknown. It may be, as Blondlot supposes, a peculiar modification of phosphorus or a mere impurity.

Since 1848 an allotropic modification is met with in commerce under the name of *red*, or, preferably, as it is never a pure red and varies in color according to circumstances, *amorphous* phosphorus. This form differs from the octahedral phosphorus in its most important attributes in a degree almost as great as do the allotropic modifications of carbon—soot, graphite, and diamond—among themselves.[iii]

---

[i] Baudrimont, *Comptes Rendus*, lxi, 857, 1866; *Zeitschr. f. Chem. N. F.*, ii, 31, 1866.

[ii] Blondlot, *Comptes Rendus*, lx, 830; *Gmelin Handbch. der Chemie* (Kraut's edition), i, Abth., 2, 103.

[iii] In the Official Report on Group III, Section 5, published by the General Direction of the Vienna Exhibition, occurs on p. 3 the following passage:—"Shortly after the non-poisonous and sparingly combustible red modification of phosphorus had been discovered *in Schrötter's laboratory*, etc." This passage, if it is to be conformable with the truth, should read: "Shortly after the non-poisonous modification of phosphorus had been discovered *by Schrötter*. I am therefore, after the lapse of twenty-seven years, once more compelled to explain that no one who at that time was work-

Amorphous phosphorus in compact pieces is an opaque reddish brown substance of imperfect metallic lustre, but where recently broken almost of an iron black. It is brittle, easily broken, and exhibits a perfectly conchoidal fracture with sharp edges. Its sp. gr. is 2·105; in hardness it lies between calcareous spar and fluor-spar. The color of the powder, and consequently of the streak, is reddish brown, exactly resembling that of ignited ferric oxide, otherwise known as colcothar.

Amorphous phosphorus is tasteless and inodorous, insoluble in all liquids which dissolve the octahedral variety, and consequently not poisonous. If taken into the stomach in considerable quantity it is excreted unchanged, and resists, therefore, the powerful oxidizing process in the animal body.

It is absolutely incapable of ignition by friction, and is therefore portable without danger. As the lumps, however, generally contain some ordinary phosphorus in small portions they have to be forwarded in water, since they might otherwise take fire if broken or rubbed. But even then the combustion proceeds very slowly. In the form of powder amorphous phosphorus may be conveyed in tin boxes without any danger.

As commonly met with in trade, the pulverulent amorphous phosphorus contains likewise small quantities of ordinary phosphorus—from 0·6 per cent downwards, according to Fresenius. It is therefore slowly oxidized on exposure to the air and has an acid reaction.

It has been also maintained that amorphous phosphorus, even in the absence of any intermixture of the ordinary variety, is slowly oxidized in the air. This is, however, doubtless an error, since the writer has preserved pure amorphous phosphorus for years, spread upon paper and freely exposed to the air without any trace of an acid reaction becoming perceptible. It is still, however, possible that there are circumstances, not yet ascertained, in which amorphous

---

ing in my laboratory has a claim to any even mentionable share in this discovery. I observed the first facts relative to this matter in 1845, on which communications may be found in the *Reports of the Sessions of the Imperial Academy of Sciences of Vienna*, Bd. i, p. 25, and in the *Memoirs*, Bd. i, p. 1, and ii, 127. Also in the *Reports of Sessions*, Bd. i. p 48; Bd. iv, p. 59, and p. 156. Other matter connected with this subject has been collated with historical accuracy in the "Reports by the Juries," Class ii, Sect. A. of the London Exhibition of 1862, drawn up by A. W. Hofmann. See art. "Phosphorus," p. 93.—A. v. S.

phosphorus, even in the absence of any admixture of the octahedral kind, may become acidified by the air. Such a behavior, though often occurring, by no means ranks among the normal attributes of this modification of phosphorus.

In addition to ordinary phosphorus and phosphorous acid, the amorphous phosphorus of commerce contains, inclusive of water, 4·622 per cent of other impurities, amongst which is always found graphite, derived from the iron vessels in which the preparation takes place.

For ignition amorphous phosphorus requires a temperature of at least 240°. In nitric acid it dissolves on account of its state of subdivision, far more readily than the common variety, because the latter, as a fused mass, offers a much smaller extent of surface for the attack of the acid. Chlorine which combines with common phosphorus with ignition has no action upon the amorphous modification. If heated in a rapid current of chlorine it burns with a yellow luminous flame.

The products of the reaction of various substances upon the two modifications of phosphorus are identical, a circumstance not observed in case of other elements occuring in allotropic forms; *e. g.*, carbon, according to the researches of Brodie, Berthelot, and Stingl.

The conversion of common phosphorus into the amorphous state is effected by exposure to light or to the prolonged action of a temperature of 240° to 250°. The transformation may be effected at 215°, but more slowly. At 260° re-conversion begins into ordinary phosphorus, the boiling-point of which, under average pressure, is about 290°. The transition from one allotropic state to the other can be more readily shown in the case of phosphorus than in that of any other element. All that is required is a glass tube closed with mercury and with several bulbs blown on its horizontal limb. Some common phosphorus is placed in the first bulb at the end of the tube, which on the application of heat ignites and consumes all the oxygen contained in the tube. The residue of the phosphorus is driven into the second bulb, converted there by cautious heating into the amorphous variety, and can then again be distilled into the third bulb in the state of ordinary phosphorus.

In 1865 Hittorf,[1] in a very valuable dissertation which essentially enlarged our knowledge of phosphorus, described a substance which he obtained on exposing amorphous phosphorus, together with lead, to a red heat in an exhausted glass tube. After cooling, black crystalline leaflets of a metallic lustre were found on the surface of the lead, and were regarded by Hittorf as phosphorus in a new allotropic modification, which he designated as the "metallic crystalline." It would be out of place to enter here upon a detailed examination of Hittorf's interesting observations, but mention must be made of the fact that common phosphorus exposed to temperatures exceeding 300° C. in closed vessels, and consequently exposed to considerable pressure, is transformed into the amorphous condition in a few minutes. As during this conversion a notable elevation of temperature takes place, the pressure upon the sides of the apparatus must be very great. Hittorf is of opinion that manufacturers engaged with the preparation of amorphous phosphorus will welcome such an abridgment of the process. The question, however, arises whether, in the treatment of large quantities, difficulties, and even dangers, might not arise far outweighing the economy of time. According to the present method, when the conversion is effected in open iron vessels in which the air finds but limited access, the process is more tedious, but free from all difficulty.

---

[1] Hittorf, *Pogg. Ann.*, cxxvi, 193.

Manufacture of Phosphorus.—The bulk of the phosphorus is still prepared in the manner indicated by Nicolas and Pelletier. From the bone-earth $Ca_3(PO_4)_2$, is obtained the primary phosphate $CaH_4(PO_4)_2$, by treatment with sulphuric acid. This is converted by heat into calcium metaphosphate, $[Ca(PO_3)_2]$, and is then mixed with charcoal powder and distilled at a strong red heat.[1] Stoneware tubes are preferable to the retorts formerly in use, and care must be taken to allow the gases to escape unhindered so that there is no pressure to overcome. The importance of this in all cases where it is requisite to catch and condense vapors escaping from ignited earthen apparatus, will appear from the fact that not a trace of carbon bisulphide can be collected if its vapor has to overcome even a very slight pressure in earthenware apparatus.

The purification of crude phosphorus from impurities present in mechanical admixture, such as charcoal, etc., is best effected by forcing it at a slight pressure through leather by means of a Real's press, kept hot.

---

[1] For further particulars see article "Phosphorus," by A. W. Hofmann, in the already quoted "Report of the Jury on the London Exhibition of 1862."

The residue (re-generated calcium tri-phosphate) is an excellent clarifying agent, especially for glycerin, and is in great request for this purpose.

The conversion of ordinary phosphorus into the amorphous condition is effected in iron boilors heated to 240°, and left open, but so that the air finds scanty admission through a narrow and rather long tube. The danger of explosion is thus obviated and very little phosphorus is burned, since the interchange of air in the boiler takes place very slowly, whilst the phosphorus consumes all oxygen so rapidly, that within the boiler scarcely a trace of this gas is present. The amorphous phosphorus thus obtained, and still always retaining some of the ordinary modification, is ground under water, boiled with soda-lye to remove octahedral phosphorus, washed, and dried.

For the preparation of phosphorus, bone-earth, as already mentioned, is generally employed. It is, however, stated that, latterly, phosphorites have come into use for this purpose in England, a step which will be ultimately necessitated by the increasing demand for phosphorus, and by the other applications of bones. Already we are compelled to procure from very remote regions this precious and useful material, whose especial destination is to maintain, unbroken, the circulation of matter; which, of course, involves a sensible increase in the price.

It is, therefore, to be lamented that a large quantity of bones remain unutilized for this great purpose from indolence or ignorance, and another from deeply-rooted religious prejudices. Invitations and proposals to obviate these evils have not been wanting, and especially as regards the last-mentioned point, they were to be found at the Exhibition. Thus Cav. Ludovico Brunetti, Professor of Pathological Anatomy at Padua, exhibited an apparatus for the incineration of dead bodies, together with the residue from the combustion of a corpse which had weighed 45 kilos. (No. 4149). The weight of the whitish residue was 1077 grms.; the process of combustion lasted three and a half hours, and the expense was merely 1·2 Austrian gulden.[1]

---

[1] See Brunetti's work "Cremazione dei Cadaveri;" also Dr. J. P. Trusen's "Die Leichenverbrennung als die geeignetste Art der Todtenbestallung," Breslau, 1855; and, finally, an excellent article by Sir Henry Thomson in the *Contemporary Review*, January, 1874, in which the subject is considered from the sanitary and economical points of view. (See *N. fr. Presse, F.*, 1874, No. 40). The best success must, therefore, be wished to the exertions of the recently-formed Cremation Society of Hamburg.

The quantity of bone-earth remaining on the incineration of bones varies according to age and to the part of the body to which they belong. On an average it is about 59 per cent. Its composition is:

Calcium phosphate, $Ca_2(PO_4)_2$, ...	85·7
Magnesium phosphate, ...	1·7
Calcium carbonate, ...	9·1
Calcium fluoride, ...	3·0
	99.5

As, however, 100 kilos. of bones yield, at most, 8 kilos. of phosphorus, more than two-thirds of the total amount present in the bones remaining in the residues, it appears that for the production of the quantity of phosphorus required, a very considerable amount of bones is required, as shown in the following figures. R. Wagner states in his valuable "Yearly Report" (xi, 267), that in the year 1864 to 1865, the production of phosphorus was:—

	Kilos.
In France and Italy, ...	100,000
In Germany and Austria, . . .	90,000
In England, ...	75,000
	265,000

for which 3,312,500 kilos. of bones were required. For the present time these figures are far too low, as will appear from the statistics of the French match trade, as given below.

Hence, it appears that in the preparation of phosphorus as generally carried on, a valuable material is consumed in a profligate manner. The endeavors of chemists to utilize it more thoroughly, are, therefore, still continued. On the one hand, the manufacture of animal charcoal or bone-black, an article of great importance in sugar-refining, and in many other branches of industry, has been greatly improved, the bones, previously freed from fat, being now heated, not in iron crucibles, but in horizontal cylinders, such as are used in the manufacture of coal-gas.[1] As by-products are obtained carbonate of ammonia, the consumption of which is daily on the increase, as also animal tar and a lighting-gas of very good quality.

---

[1] G. Lunge's description of the process of bone-distilling introduced in England. *Wagner Jahresber.* 1867, 199; *Dingl. Pol. Journ.*, clxxxiv, 513.

The tar is as yet a mere burden to the manufacturers, since it has not yet been brought into use, and is, therefore, disposed of by burning, which is not without difficulty. The time is, however, certainly not far distant when a product so rich in basic nitrogenous compounds will find a profitable utilization.

(To be continued.)

EDISON'S MICRO-TASIMETER.[1]

An important outgrowth of Mr. T. C. Edison's experiments with his carbon telephone transmitter, is an instrument for detecting minute changes of temperature, which, he claims, greatly surpasses the thermopile in delicacy.

In determining the thickness of carbon buttons best suited to the transmission of articulate sounds, he found that, within certain limits, increased thickness gave increased sensitiveness; but after using the instrument a short time it became inarticulate, and, finally, inoperative. An investigation showed that this was the result of expansion of the hard rubber handle by the heat of the hand.

This difficulty was soon overcome by a different mode of attaching the carbon button, but it had suggested a new use for its extreme sensitiveness.

The micro-tasimeter is represented, in perspective in Figs. 1 and 2, in section in Fig. 3, and the plan upon which it is arranged in the electric circuit is shown in Fig. 4.

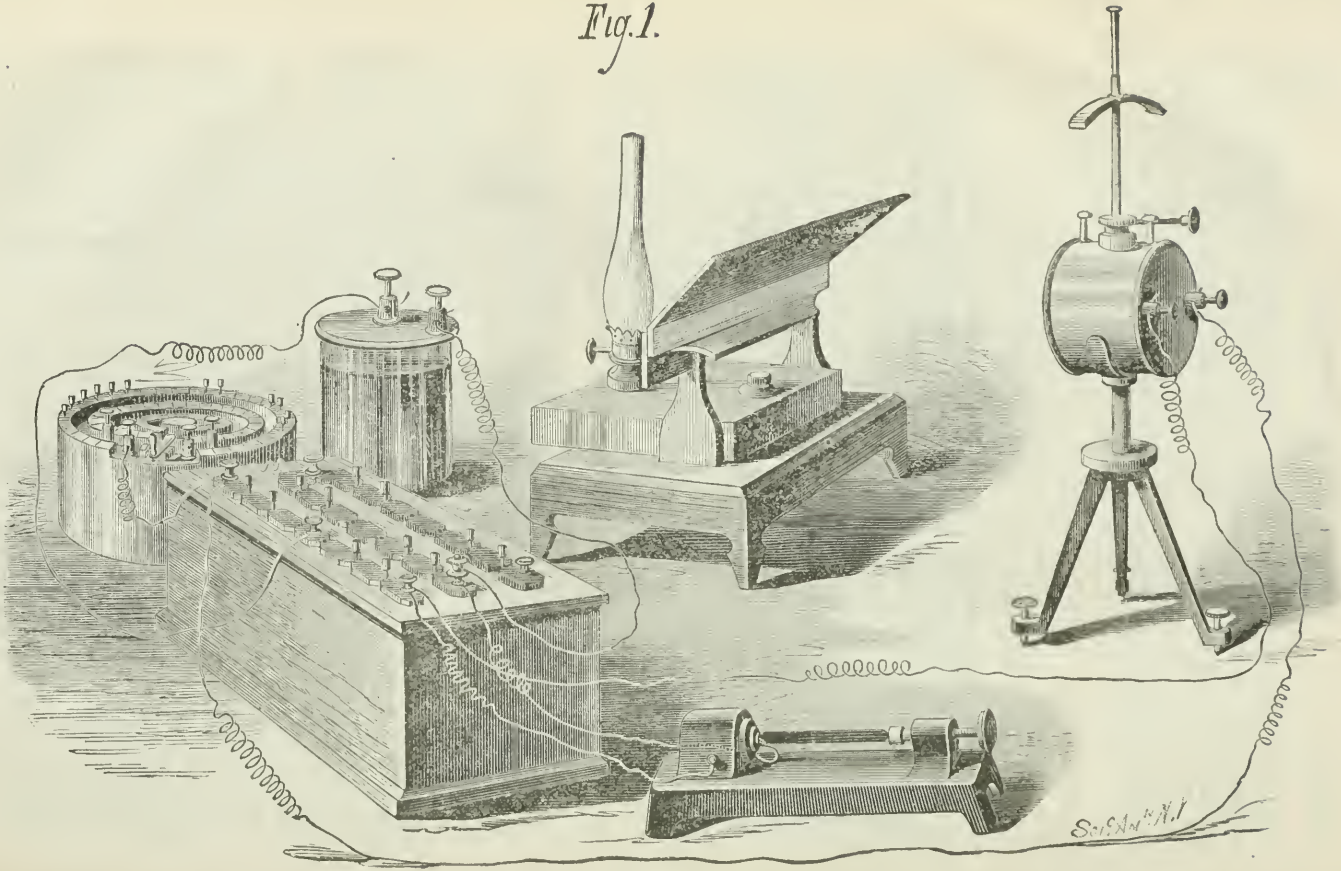
The instrument consists, essentially, in a rigid iron frame for holding the carbon button, which is placed between two platinum surfaces, one of which is fixed and the other movable, and in a device for holding the object to be tested, so that the pressure resulting from the expansion of the object acts upon the carbon button.

Two stout posts, *A*, *B*, project from the rigid base piece, *C*. A vulcanite disk, *D*, is secured to the post, *A*, by the platinum-headed screw, *E*, the head of which rests in the bottom of a shallow circular cavity in the centre of the disk. In this cavity, and in contact with the head of the screw, *E*, the carbon button, *F*, is placed. Upon the outer face of the button there is a disk of platinum foil, which is in electrical communication with the battery. A metallic cup, *G*, is placed in contact with the platinum disk, to receive one end of the strip of whatever material is employed to operate the instrument.

---

[1] We are indebted to Mr. Edison for the accompanying illustrations.

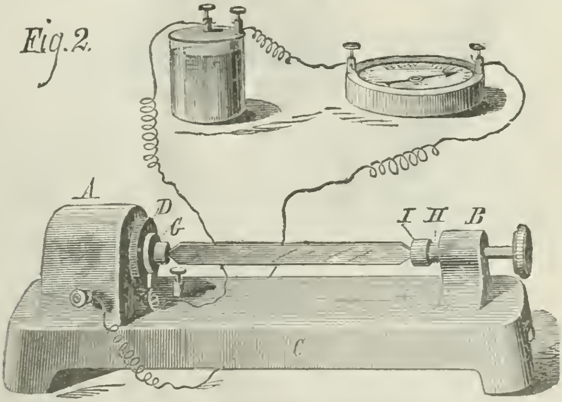
Fig. 1.



EDISON'S MICRO-TASIMETER.

The post *B* is about 4 inches from the post *A*, and contains a screw-acted follower, *H*, that carries a cup, *I*, between which and the cup *G* is placed a strip of any substance whose expansibility it is desired to exhibit. The post *A* is in electrical communication with a galvanometer, and the galvanometer is connected with the battery. The strip of the substance to be tested is put under a small initial pressure, which deflects the galvanometer-needle a few degrees from the neutral point. When the needle comes to rest, its position is noted. The slightest subsequent expansion or contraction of the strip will be indicated by the movements of the galvanometer-needle. A thin strip of hard rubber, placed in the instrument, exhibits extreme sensitiveness, being expanded by heat from the hand, so as to move through several degrees the needle of a very ordinary galvanometer, which is not affected in the slightest degree by a thermopile facing and near a red-hot iron. The hand, in this experiment, is held a few inches from the rubber strip. A strip of mica is sensibly affected by the heat of the hand, and a strip of gelatin, placed in the instrument, is instantly expanded by moisture from a dampened piece of paper held 2 or 3 inches away.

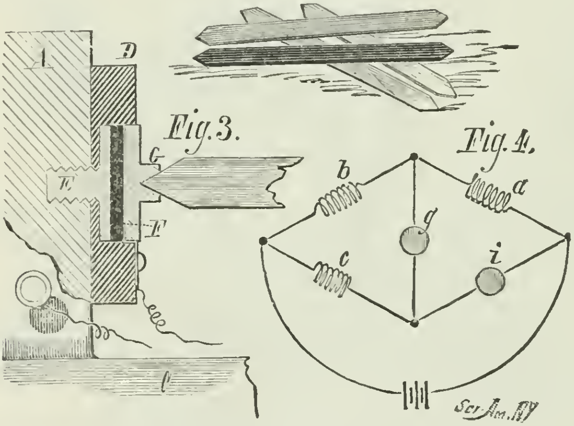
Fig. 2.



For these experiments the instrument is arranged as in Fig. 2, but for more delicate operations it is connected with a Thomson's reflecting galvanometer, and the current is regulated by a Wheatstone's bridge and a rheostat, so that the resistance on both sides of the galvanometer is equal, and the light-pencil from the reflector falls on 0° of the scale. This arrangement is shown in Fig. 1, and the principle is illustrated by the diagram, Fig. 4. Here the galvanometer is at *g*, and the instrument which is at *i* is adjusted, say, for example, in 10 ohms resistance. At *a*, *b* and *c*, the resistance is the same. An increase or diminution of the pressure on the carbon button by an infinitesimal expansion or contraction of the substance under test, is indicated on the scale of the galvanometer.

The carbon button may be compared to a valve, for, when it is compressed in the slightest degree, its electrical conductivity is increased, and when it is allowed to expand it partly loses its conducting power.

The heat from the hand, held 6 or 8 inches from a strip of vulcanite placed in the instrument—when arranged as last described—is sufficient to deflect the galvanometer-mirror so as to throw the light-beam completely off the scale. A cold body placed near the vulcanite strip will carry the light-beam in the opposite direction.



Mr. Edison proposes to make application of the principle of this instrument to numberless purposes, among which are delicate thermometers, barometers and hygrometers.

Speaking of this instrument, Mr. Edison says: "The heat-measurer was described and experiments shown to Professor Langley, the well-known astronomer of the Alleghany Observatory, some six months ago. On his suggestion, at the time, that it ought to be worked up as a very valuable boon to science, especially in the line he was investigating (that is, measuring the heat of the stellar spectra), I tried many experiments with it, and devised the form given. This apparatus was described to various members of the National Academy of Sciences, held at Washington, April 17th, 18th and 19th, 1878, and the Washington *Star* and *Union*, newspapers published then, gave a description of the instrument."

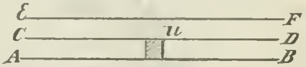
NOTE ON THE POWER OF RUNNING WATER TO HOLD MATTERS IN SUSPENSION.

By J. P. Frizell, C. E.

Mr. Herschel has rendered an acceptable service by collecting the labors of engineers on this subject, performed at different times, and presenting them in one view. The following remarks are suggested by his recent articles in the Journal.[1]

M. Dupuit's theory, quoted by Mr. H., calls for a word of comment. The proposition, "Flowing water can hold bodies in suspension which are much more dense than it," is undisputed and indisputable. It may be also true that "the lower planes of the stream can carry more voluminous solids, or more of them, than those higher up," though not for the reason contemplated by M. Dupuit. As to the statement, however, which embodies the substance of his theory, viz., "The power of suspension depends upon the relative velocity of the filaments, and is greater the greater this relative velocity is," I hold that a more fanciful proposition was never reduced to writing. It may be observed, that this theory is more fully stated in the Humphrey's Abbott Report, p. 139, thus: "Dupuit demonstrates (Chapter V, "Etudes Théoriques et Pratiques sur le Mouvement des Eaux Courantes") that the power of suspension is due to the fact that the different layers of water are actuated by different velocities, and thus exert different pressures upon the different sides of the suspended atoms." "Hence," continues the report, "the greater the difference in the velocity of the consecutive layers, the greater will be the power of suspension."

Fig. 1.



Let us ask those who have adopted this theory, to reflect a little more seriously upon it. Let $A\,B$, $C\,D$, $E\,F$, Fig. 1, be horizontal planes indefinitely near each other, in a mass of water moving from A toward B, $C\,D$ is moving a little faster than $A\,B$, $E\,F$ a little faster than $C\,D$. Let M be a minute particle of sediment, clay, for instance, twice the specific gravity of water. The assumption is that the upward pressure of $A\,B$ exceeds the downward pressure of $C\,D$, by an amount equal to the difference between the weight of M, and an equal particle of water, on every element of the plane. Is this consistent with the commonest conception of the nature of force and motion? Force or pressure is *tendency to produce motion.* There can be no unbalanced pressure in a mass of water, without a corresponding motion. Strictly speaking, unbalanced pressure in a mass of water is impossible, because the slightest tendency that way instantly results in motion. Yet the theory only contemplates a horizontal movement from A toward B. It is, therefore, self-contradictory.

---

[1] See vol. cv, p. 330.

Again it is assumed, that, in virtue of the relative velocity of $C D$ and $A B$, every element of the plane $A B$ has the power of sustaining a particle of clay reaching from $A B$ to $C D$, for if one element possesses this power, every other element must. The plane $C D$, also has, for the like reason, a similar power, with reference to the plane $E F$. Therefore, in virtue of the relative velocity between $E F$ and $A B$, the latter plane has the power of bearing a stratum or lamina of clay reaching to the former; *i. e.*, the relative velocity being twice as great, the sustaining power is twice as great. Continuing this reasoning with reference to planes higher up, we reach the conclusion, that if M. Dupuit has demonstrated the power of water to carry, in accordance with this principle, a single particle of clay, he has also demonstrated its power to carry a block of limestone or coherent clay a foot in diameter. When we further reflect that water, in a condition to take up much sediment, does not move in parallel layers, or in anywise approaching thereto, we must admit that M. Dupuit's theory is a false deduction from erroneous premises. It is but the simulacrum of a simulacrum—the shadow of a shadow.

But the question still remains, Whence does water derive its power of sustaining matters denser than itself?

A spherical mass of indurated clay, 1 foot diameter, thrown into water 24 feet deep, will reach the bottom in less than three seconds.

A similar mass, $\frac{1}{100}$ of a foot in diameter, will require upwards of 25 seconds to reach the bottom. A finer subdivision will involve a slower rate of sinking, till, when reduced to impalpable dust, it may be 48 hours before the last particle reaches the bottom.

The cause of this is very obvious. The force which impels a body to sink, is its weight, which is proportional to the cube of its diameter. The force which resists sinking is the action of the water on the cross-section of the body, being proportional to the square of the diameter. A diminution of the diameter reduces the sinking force in a greater ratio than the retarding force, and, consequently, diminishes the sinking velocity.

The velocity with which a spherical mass sinks, may be determined as follows:

Let d be the diameter of the mass in feet.
v the velocity in feet per second.
ρ the specific gravity of the material.

The weight of the body is $0{\cdot}5236\ d^3\ \rho \times 62{\cdot}3$.

Its effective weight in water is $62{\cdot}3 \times 0{\cdot}5236\ d^3\ (\rho - 1)$.

The resistance of the water $= 0{\cdot}51 \times 62{\cdot}3 \times 0{\cdot}7854\ d^2 \frac{v^2}{2g}$ (see Rankine's "Applied Mechanics," p. 599).

When the velocity is uniform, the resistance is equal to the effective weight, and $0{\cdot}5236\ d\ (\rho - 1) = 0{\cdot}51 \times 0{\cdot}7854 \frac{v^2}{2g}$; whence,

$v = \sqrt{\frac{0{\cdot}5236\ d\ (\rho - 1)\ 2\ g}{0{\cdot}51 \times 0{\cdot}7854}}$. For the case of clay we may put $\rho = 2$

Putting $d = 1$, we have, for the velocity of a spherical mass of clay, 1 foot diameter, $v = 9{\cdot}17$ feet per second; for $d = \frac{1}{100}$, $v = 0{\cdot}917$ feet per second.

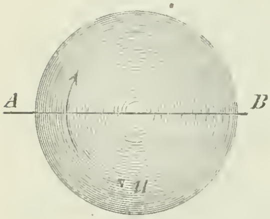
Putting $v = \frac{1}{7200}$, we have:

$$d = \frac{0{\cdot}51 \times 0{\cdot}7854}{2\ g \times 0{\cdot}5236 \times (7200)^2} = 0{\cdot}00000000229$$ foot, which is the diameter of a spherical particle of clay, capable of sinking at the rate of 6 inches an hour.

A solid particle heavier than water, and suspended therein, never ceases to sink with the full velocity determined by its size and specific gravity. Yet a particle, of appreciable size, may remain suspended long enough to travel great distances. In this respect, its slowness of sinking is aided by the internal movements of the water.

When water moves in an irregular channel, with a rapid fall, much of the mechanical energy due to the fall is wasted; that is, it does not contribute to the forward movement of the water, but expends itself, mainly, in gyratory movements around horizontal and vertical axes. The inequalities of a vertical wall along which water flows lead to vertical eddies; those of the bed, to rotary movements around horizontal axes. These latter are most effective in the transportation of material. Consider how a particle of matter is affected by one of these whirls. Let *A B*, Fig. 2, be the horizontal line through the centre of such a whirl. The particle, *M*, participates in the whirling movement and, at the same time, obeys the action of gravity. The latter causes it to recede from the centre so long as it is below the line *A B*. When the whirling movement brings it above the line *A B*, the action of gravity causes it to approach the centre. Its movement thus consists of a series of oscillations, alternately approaching and receding from the centre, but making no progress toward the bottom. It is easy to conceive that a particle of gravel, capable of sinking in still water at the rate of 1 foot per second, may, while within the influence of a horizontal eddy, float as securely as a particle of sawdust. It escapes from one eddy only to fall within the influence of another. If it approaches the bottom, it may be sustained by one of those eddies till a more general gyratory movement lifts it into the higher regions of the stream, while the still more general movement of the current sweeps it forward.

Fig. 2.



The movements which take place in deep and rapid currents, flowing in irregular channels, are complex in the extreme: horizontal and vertical whirls, in which each particle of water has a velocity inversely proportional to its radius of gyration; movements in which each individual particle conforms to this law, while the general mass forms part of a greater whirl; wave movements proper, in which each particle tends to revolve around its position of rest with uniform angular velocity. In very deep water this tendency is fully realized, and the path is a circle of greater or less diameter at the surface, according to the magnitude of the disturbing cause, diminishing to nothing at the bottom. In shallower currents the movement is elliptical at the surface, and rectilinear at the bottom, All these movements, diversified by the form of the bed, are superposed upon and confounded with one another; and, with the general forward movement, in a manner to defy the most persistent faculty of analysis.

THE GRAMME DYNAMO-ELECTRIC MACHINE FOR PRODUCING ALTERNATING CURRENTS.[I]

The recent improvement in the Jablochkoff system of electric illumination, and that which has given to it its present success, is the employment of an alternating current of electricity for establishing the electric arc between the carbon points. If the Jablochkoff candle[II] is used with a continuous current, the positive carbon is consumed at twice the speed of the negative, but with a rapidly alternating current instead of a continuous one, the carbon will consume at an equal rate, each being alternately positive and negative to the other, and an alternating current possesses this further advantage, namely, that each stick of carbon is kept beautifully pointed instead of rough and irregular, and this symmetrical consumption of the carbonaceous matter is a great source of steadiness in the light.

The Jablochkoff candle may be used with advantage with any dynamo-electric machine which produces an alternating current, or by a continuous-current machine fitted with a commutator, by which the direction of its current is reversed every few seconds, but this arrangement for obtaining from a continuous-current machine a series of currents in alternate directions, can only be accompanied by great loss of electricity, and, therefore, of motive power, and it has been found much more economical and advantageous to use machines whose currents are originally generated in alternate directions. Of these, the machines of Holmes, of the Société l'Alliance, and of some others, would answer the purpose, but M. Gramme has designed a machine which is, to some extent, a modification of his previous arrangement, which not only produces an alternating current of electricity, but is capable of dividing that current, so as to supply electricity to four, six, sixteen, or more electric lamps, or candles. It is this new machine of M. Gramme which is now employed for producing the electric currents by which some 300 electric lamps are nightly illuminating the boulevards and public buildings of Paris.

This machine, the essential features of which are shown in the figure, consists of a ring of soft iron similar to that used in the earlier continuous-current machines of the same inventor. This ring

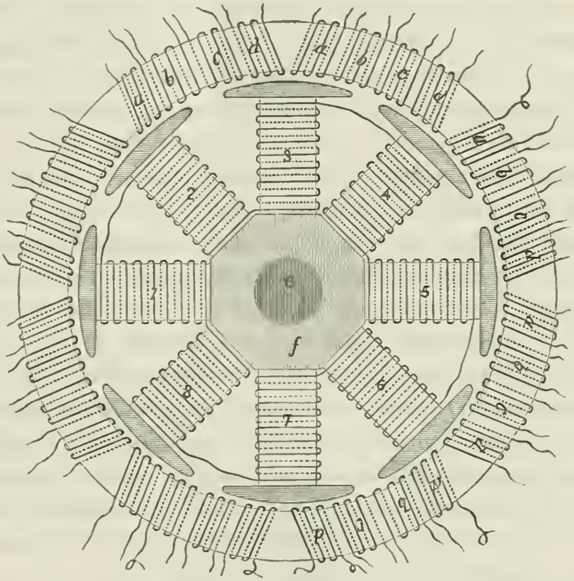
---

[I] Condensed from *Engineering*. The figure from sketch sent by Prof. E. Thomson.

[II] See vol. civ, p. 142

is, like its predecessors, wound with coils of insulated copper wire, but, unlike those of the earlier machines, the direction of winding is alternately right and left handed, the wire being wound in one direction, so as to cover one-eighth part of the circumference of the ring, then changing its direction, being wound in the contrary way over the next eighth part, and so on round the ring, each of the eight sections of the ring being wound in the reverse direction to that in which its two contiguous sections are wound. Thus, while the earlier Gramme ring might be described as an electro-magnet bent round in a circle and joined to itself, the ring of the new machine may be looked upon as eight curved electro-magnets placed end to end with their similar poles in contact, so as to form a circle. This ring is rigidly fixed in a vertical position to the solid framing of the apparatus, the inducting electro-magnets revolving within it. Here again it differs from the continuous-current machine in which the magnets were fixed, and the ring was rapidly rotated in the magnets fixed between their poles. The electro-magnets, of which there are eight, are fixed radially to a central boss, *f*, revolving upon a horizontal steel shaft, *e*, running in suitable bearings attached to the framing, and an external pulley enables the machine to be driven by a band from a steam-engine or other motor. The radial electro-magnets are alternately right and left handed in the direction in which their coils are wound, so that if they be numbered 1, 2, 3, 4, etc., up to 8, respectively, those represented by even numbers will have one polarity when a current is sent through them all together, while those whose numbers are uneven will have an opposite polarity. The poles farthest from the central boss, in all the magnets, are spread out so as to increase the area of the magnetic field by which electric currents are induced in the coils of the ring.

In the old machine of M. Gramme, the electro-magnets were excited by the current from a special Gramme ring mounted on the same shaft as the two rings which produced the available current, and the current from the first ring was exclusively devoted to exciting the electro-magnets. In further improvements upon his continuous-current machine, M. Gramme dispensed with an extra and special ring for charging the magnets, and devoted a portion of the current from a single ring to that purpose, two coils being wound on the same ring. In the present machine, however, there is no self-contained apparatus for producing the current by which the electro-magnets are charged, although there is nothing to prevent an ordinary Gramme machine being attached to the same shaft. It is found more convenient, however, to use the new machine simply as an apparatus for dividing the current, and for giving to it a reciprocating nature, and, therefore, an altogether separate electro-motor is employed. An ordinary voltaic battery of sufficient power would answer the purpose, but in practice a small and separate Gramme machine of the continuous-current type is employed, driven by a separate strap, and the current from this machine being caused to traverse the coils of the rotating radial electro-magnets, they are magnetized to saturation with but a small expenditure of motive power.



Each of the eight sections of the induction-ring are made up of four sub-sections, *a*, *b*, *c*, *d*, *a*, *b*, *c*, *d*, etc., all of which, in any one section, are wound in the same direction. By coupling the coils of these sub-sections in various ways, a division of the current may be made into 32, 16, 8, or only 4 circuits, and this is one of the most valuable qualities of the system.

From a consideration of the above description, it will be seen that all the sub-sections or coils marked *a* are influenced by the rotating magnets in precisely the same manner, for the influence of a north pole upon a coil wound in a positive direction, is precisely the same as that of a south pole upon a coil wound in a negative direction, and similarly the currents induced in all the coils marked *b* are similar in direction to one another, no matter what may be the position of the rotating magnets. And in order to obtain four currents from the machine by which four lamps may be illuminated, all that is necessary is to connect together in series all the coils marked *a* for one circuit, all the coils marked *b* for a second circuit, all the coils marked *c* for a third circuit, and all the coils marked *d* for a fourth circuit. As the induction-rings are fixed, there is no difficulty in "tapping" the currents from the machine, and the apparatus is fitted with terminal screws on the exterior of the rings by which that can be effected, and by which variations in the method of coupling up may be made.

The current for the small machine is led to the rotating magnets through flat brushes composed of silvered copper wire fixed to the framework of the machine, and rubbing against two insulated drums or cylinders of copper, the first being connected to one end of the magnet-circuit, and the second to the other.

When the shaft carrying the magnet is rotated, the expanded magnetic poles pass close to the coils of the induction-ring, and in so doing induce within them currents of electricity, the strength of which depends upon the intensity of the magnetic field brought over them, and increases with the speed of rotation.

The new Gramme machine, as at present constructed, is made in three sizes. The largest is capable of supplying the current to 16 Jablochkoff candles, at a speed of 600 revolutions per minute, and absorbing a motive power of about 16 horse-power, costs, with the smaller machines for charging the magnets, 10,000 francs (= £400), its length, including the shaft and pulley, is 35 in., its width 30 in., and its height about the same; the total weight is a little over 12½ cwt. The second size machine requires 6 horse-power to drive it, at a speed of 700 revolutions per minute, and supplies the light to 6 Jablochkoff candles, and costs with its small machine, 5000 francs (£200). It measures 27 in. in length, 15 in. in width, and 20 in. in height, and weighs rather over 5 cwt. The smallest size actuates, at a speed of 800 revolutions per minute, 4 Jablochkoff lights, and absorbs 4 horse-power of motive power. Its dimensions are as follows: Length, 21 in ; width, 15 in.; height, 18 in.; and its total weight is about 3½ cwt. In addition to these three sizes, M. Gramme has a new machine in hand, which differs in construction, in several material points, from those to which we have referred, and from which he hopes to effect a saving in both the prime cost and the cost of working the machine. It is designed for use with 2 Jablochkoff candles.

It will be seen from the above figures that the power absorbed is almost exactly 1 horse-power for each candle, and the results of a year's working of the system at the Hotel and Magazins du Louvre, very closely supports that estimate.

That M. Jablochkoff has solved the problem of producing a steady electric light, requiring but little attention, and suitable for street illumination of a very beautiful order, must be self-evident to all visitors to Paris at the present time.

Whether the system, however, is a success in an economical and commercial point of view, is another question altogether, and remains to be proved. We are rather inclined to the opinion that in its present stage it is rather costly, although light for light it will compare favorably with gas.

The whole system, much as it adds to the beauty and attractions of the city of Paris, must still be looked upon as in its childhood; it is rather more than a step, it is a long stride in the right direction, and we cannot but believe that further improvements, both in the construction of the machines for generating the electrical currents, and in the apparatus for converting those currents into centres of illumination, will burst through all obstructions placed in its path.

Absorption of Carbonic Oxide by Living Organisms.—N. Gréhaut has experimented with mixtures of air and minute portions of carbonic oxide. He finds that a man or an animal, when compelled for a half-hour to breathe an atmosphere containing only $\frac{1}{779}$ of carbonic oxide, absorbs that gas in sufficient quantities to saturate about half of the red globules of the blood, so that they become incapable of absorbing oxygen. In an atmosphere containing $\frac{1}{1449}$ of carbonic oxide, about a quarter of the red globules are similarly saturated. These results are interesting and important in relation to physiology and hygiene.—*Comptes Rendus.* C.

DESCRIPTION OF A MONTGOLFIER RAM BUILT BY THE I. P. MORRIS COMPANY, PHILADELPHIA.

By Washington Jones.

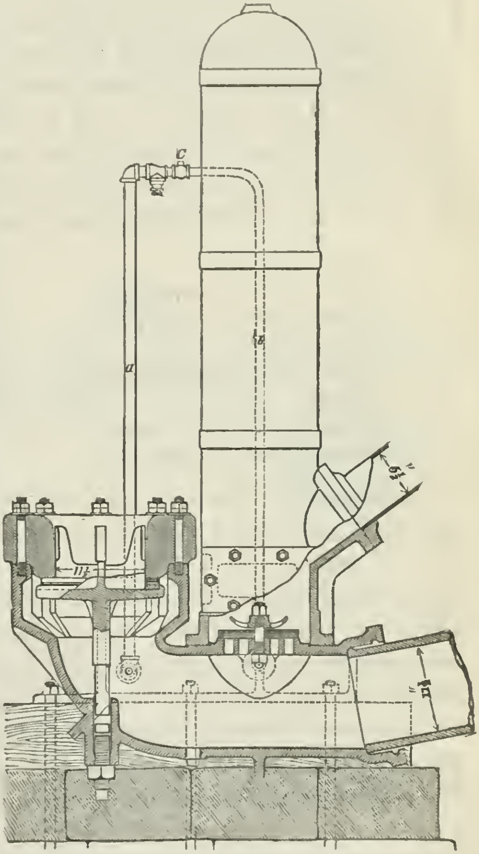
Recently, the I. P. Morris Company made at their Port Richmond iron works, to be used for the purpose of irrigating the higher lands of a coffee plantation in South America, a hydraulic ram, whose capacity is greater than that of any other known to them. The following data were furnished by the purchaser with his order. As will be noticed, they cover the most important points, except the quantity of water available, which, therefore, was assumed to be ample:

Height of fall, ...	9 ft. 10 in.
Elevation of reservoir, . . .	63 " 10 "
Diameter of inlet-pipe, . .	$11\frac{1}{2}$ "
Length " "	52 " 4 "
Diameter of ascension-pipe, . .	$5\frac{1}{2}$ "
Length " " " . .	127 " 8 "
Diameter of waste-valve, . .	$11\frac{1}{2}$ "
Contents of air-vessel, . . .	$4\frac{2}{10}$ cu. ft.

The capacity of the air-vessel was increased to $5\frac{1}{2}$ cu. ft., as the additional expense of the material was amply compensated by the known advantage of a large air-cushion, in partially relieving this type of machine from the violent shocks inseparable from its action. The minor details, and their disposition, were determined upon by the constructors, after consideration and information obtained by reference to Crecy, London *Engineer*, and Spon's "Dictionary of Engineering," wherein were found descriptions of several which, though of small capacity, were of assistance in forming a conclusion. The results were embodied in the machine, of which the following is a description. A reference to the cut will make the construction more readily understood:

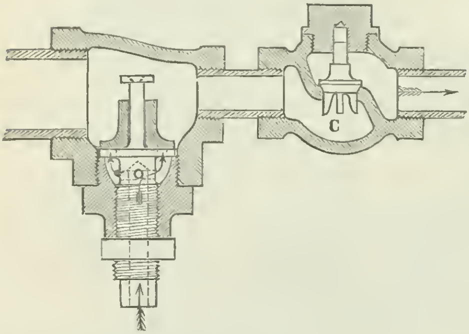
The body of the ram is a cylindrical pipe $11\frac{1}{2}$ inches bore and $1\frac{1}{8}$ inches thick, strengthened with flanges. It curves upwards, at the rear or discharge end, until the axis of bore becomes vertical, when the bore is enlarged to $19\frac{1}{2}$ inches, so as to form a chamber for the waste-valve. Several vertical ribs join the flange, provided for the valve-seat at top of chamber, with the main body of the ram. About midway the length of the body is the seat for water-valve and the air-vessel. A horizontal flange on each side of body, strongly ribbed, serves to hold the machine to timbers which rest upon stone foundations. Six bolts pass through all, with keys and plates at lower ends. The water-valve is of gum, and seats upon a grating cast on the body of ram, and is held in position by a stud carrying a guard. This valve is encased by the air-vessel, and access to it is had through a door. The body of the waste-valve is of cast iron, strongly ribbed, and is guided, at its upper end, by wings sliding within the bore of valve-seat, and, at its lower end, by a stem working in a hole bored in the body of ram. This hole is fitted, at its lower end, with a long tap-bolt, which is used to adjust the drop of the valve and the number of beats per minute at such a point, found by trial, where best efficiency of ram is obtained. A piece of gum, interposed between the ends of stem and tap-bolt, serves to soften the blow of descending valve. The face of waste-valve is a ring of wrought iron, riveted to the valve with three thicknesses of heavy sole-leather between them, so as to give some elasticity, and thereby diminish the shocks given by the valve closing. The waste-valve seat is of cast iron, made heavy (about five times the weight of the valve), and firmly bolted to the body of ram. The supply is carried through cast iron pipes having socket-joints, and their thickness diminishes from $1\frac{1}{8}$ inches at the junction with ram, to $\frac{5}{8}$ inch at the upper end. The ascension-

Fig. 1.



pipe is welded wrought iron tube, 5½ inches diameter, joined by flanges. The apparatus for supplying air to the air-vessel, is essentially that designed by Mr. Bolèe (see Spon's "Dictionary of Engineering," article "Hydraulic Machines," folio 1972), with a modification of the "snifting-valve," which compels all the air admitted through it to enter the air-vessel; or if in excess, as in this case provided so, the surplus escapes between the under side of valve-seat and the top of screw-plug, on which the valve is mounted, through an opening adjustable by means of the screwed shank of the valve seat. The supply air passes upwards through the hollow shank, thence outwards, through holes, into the space below the valve-seat; the valve-seat is perforated with several holes, through which the air rises and lifts the valve. When the valve closes, the return of any air is prevented, but if the seat be raised from the top of the plug, a portion of it, more or less, as desired, passes between them and escapes (see enlarged view of snifting-valve). The valve is placed high enough to be above floods, and its operation is as follows: The tube, *a*, is of 1 inch gas-pipe, and it rises, from the point of its attachment to body of ram, to a suitable height, and carries the snifting-valve and a check-valve; it is then joined by a ½ inch gas-pipe, *b*, which descends and meets a check-valve, attached to the ram, immediately under the air-vessel. When the waste-valve opens, the water contained in the pipe, *a*, falls, and produces a vacuum, when the air enters, through the snifting-valve, into pipe *a*. When the stroke recurs and waste-valve closes, the water rises in pipe *a*, and displaces the air, which, under pressure, opens the check-valve *c*, whence it passes, through pipe *b* and check-valve *d*, into body of ram, and ascends into the air-vessel. This occurs each stroke, so that supply of air is continuous. Any surplus is discharged by the modification before described.

Fig. 2.



Upon completion the apparatus was set up in position, and pipes attached; about 35 feet of ascension-pipe, placed vertically, and 48 feet of supply-pipe, connected with a tank holding enough water for five minutes run, set 10 feet high (or the height of fall) above ram. Short trials were made, mainly to prove the work, and, if possible, to get adjustment of waste-valve, giving best results as to quantity of water raised with least hammer of valve, but the limited supply of water, and the temporary manner in which the arrangements were obliged to be made, prevented any rigid tests, and, consequently, no results of value were obtained.

AERIAL ECHOES.[1]

By Joseph Henry.

During the year 1877, and also in 1876, a series of experiments was made on the aerial echo, in which I was assisted in the first series by General Woodruff, engineer of the third lighthouse district, and in the second series by Edward Woodruff, assistant engineer of the same district. These experiments were made principally at Block Island, but also at Little Gull Island. Especial attention has been given to this phenomenon, which consists in a distinct echo from the verge of the horizon in the direction of the prolongation of the axis of the trumpet of the siren, because the study of it has been considered to offer the easiest access to the solution of the question as to the cause of all the abnormal phenomena of sound, and also because it is in itself an object of much scientific interest.

In my previous notice of this phenomenon, in the report of the Lighthouse Board for 1874, I suggested that it might be due to the reflection from the crests of the waves of the ocean; but as the phenomenon has been observed during all conditions of the surface of the water, this explanation is not tenable.

Another hypothesis has been suggested, that it is due to a flocculent condition of the atmosphere, or to an acoustic invisible cloud, of a density in different parts differing from that of the general atmosphere at the time. To test this hypothesis experimentally, the large trumpet of the siren was gradually elevated from its usual horizontal position to a vertical one. In conception, this experiment appears very simple, but, on account of the great weight of the trumpet, it required the labor of several men for two days to complete the arrangements necessary to the desired end. The trumpet, in its vertical position, was sounded at intervals for two days, but in no instance was an echo heard from the zenith, but one was in every case produced from the entire horizon. The echo appeared to be somewhat louder from the land portion of the circle of the horizon than from that of the water. On restoring the trumpet to its horizontal position, the echo gradually increased on the side of the water, until the horizontal position was reached, when the echo, as usual, appeared to proceed from an angle of about twenty degrees of the horizon, the middle of which was in the prolongation of the axis of the trumpet. A similar experiment was made with one of the trumpets of the two sirens at Little Gull Island. In this case the trumpet was sounded in a vertical position every day for a week with the same result. On one occasion it happened that a small cloud passed directly over the island on which the lighthouse is erected, and threw down on it a few drops of rain. At the moment of the passage of this cloud the trumpet was sounded, but no echo was produced.

---

[1] From report of the Lighthouse Board, 1877.

From these experiments it is evident that the phenomenon is in some way connected with the horizon, and that during the continuance of the experiment of sounding the trumpets while directed toward the zenith, no acoustic cloud capable of producing reflection of sound existed in the atmosphere above them.

Another method of investigating this phenomenon occurred to me, which consisted in observing the effects produced on the ears of the observer by approaching the origin of the echo. For this purpose, during the sounding of the usual interval of twenty seconds of the large trumpet at Block Island, observations were made from a steamer, which proceeded from the station into the region of the echo, and in the line of the prolongation of the axis of the trumpet, with the following results:

1. As the steamer advanced, and the distance from the trumpet was increased, the loudness of the echo diminished, contrary to the effect of an echo from a plane surface, since in the latter case the echo would have increased in loudness as the reflecting surface was

approached, because the whole distance traveled by the sound-wave to and from the reflector would have been lessened. The effect, however, is in accordance with the supposition that the echo is a multiple sound, the several parts of which proceed from different points at different distances of the space in front of the trumpet, and that as the steamer advances toward the verge of the horizon, it leaves behind it a number of the points from which the louder ones proceed, and thus the effect upon the ear is diminished as the distance from the trumpet is increased.

2. The duration of the echo was manifestly increased, in one instance, from five seconds, as heard at the mouth of the trumpet, to twenty seconds.

This would also indicate that the echo is a multiple reaction of varying intensities from different points, and that at the place of the steamer the fainter ones from a greater distance would be heard, which would be inaudible near the trumpet.

3. The arc of the horizon from which the echo appeared to come was also increased, in some cases, to more than three times that subtended by the echo at the place of the trumpet. This fact again indicates that the echo consists of multiple sounds from various points at or near the surface of the sea, the angle which the aggregate of these points subtend necessarily becoming greater as the steamer advances.

But perhaps the most important facts in regard to the echo are those derived from the series of observations made in regard to it by Mr. Henry W. Clarke, the intelligent keeper of the principal lighthouse station on Block Island, and by Joseph Whaley, keeper of the Point Judith Lighthouse. Mr. Clark was furnished with a time-marker to observe the duration of the echo, and both were directed to sound the trumpets every Monday morning for half an hour, noting the temperature, the height of the barometer, the state of the weather as to clearness or fog, the direction and intensity of the wind, and the surface of the ocean.

From the observations made at these two points, for more than two years at one station, and over a year at the other, the echo may be considered as produced constantly under all conditions of weather, even during dense fogs, since at Block Island it was heard 106 times out of 113, and at Point Judith 50 times out of 57, and on the occasions when it was not heard the wind was blowing a gale, making a noise sufficiently intense to drown the sound of the echo. These results appear to be sufficient to disprove the hypothesis that the phenomenon is produced by an acoustic cloud accidentally situated in the prolongation of the axis of the trumpet. It must be due to something more permanent in its effects than that from a portion of air differing from that of the general atmosphere in temperature or density, since such a condition cannot exist in a dense fog embracing all the region of the locality of the phenomenon. Indeed, it is difficult to conceive how the results can be produced, even in a single instance, from a flocculent portion of atmosphere in the prolongation of the axis of the trumpet, since a series of patches of clouds of different temperature and densities would tend to absorb or stifle by repeated reflections a sound coming from their interior rather than to transmit it to the ear of the observer.

The question, therefore, remains to be answered: What is the cause of the aerial echo? As I have stated, it must in some way be connected with the horizon. The only explanation which suggests itself to me at present is, that the spread of the sound which fills the whole atmosphere from the zenith to the horizon with sound-waves may continue their curvilinear direction until they strike the surface of the water at such an angle and direction as to be reflected back to the ear of the observer. In this case the echo would be heard from a perfectly flat surface of water, and as different sound-rays would reach the water at different distances and from different azimuths, they would produce the prolonged character of the echo and its angular extent along the horizon.

While we do not advance this hypothesis as a final solution of the question, we shall provisionally adopt it as a means of suggesting further experiments in regard to this perplexing question at another season.

Gnomonic Projection.—In presenting De Chancourtois's gnomonic atlas to the academy, Faye called attention to the advantage which the gnomonic projection possesses in representing the great circles of the sphere by simple, straight lines. Chancourtois employs a projection upon the eight faces of an octahedron, and Faye considers his method peculiarly desirable for geographical, geological, and lunar maps.—*Comptes Rendus.* C.

RAILWAY BRAKES.

A very interesting and important series of experiments, for the purpose of determining the degree of force with which it is desirable that brake-blocks should be pressed upon the wheels of a train, has recently been conducted upon the London, Brighton and South-Coast Railway, under the supervision of Captain Douglas Galton, C. B., F. R. S., and of Mr. Westinghouse.

Although continuous brakes have now been in use for many years, there have, hitherto, been no data for arriving at any certain conclusion with regard to the force with which they should be applied to produce the best results; and the widest differences of opinion, or rather of conjecture, have prevailed upon the subject. It has even been uncertain whether brakes were more effectual when the wheels were skidded and suffered to slide along the rails, or when the blocks were applied with a force just short of that by which skidding would be produced. It will be remembered that at the trials at Newark in 1875, conducted under the control of the Royal Commission on Railway Accidents, a crude attempt was made to determine the difference between the effects of skidding and of merely impeding rotation; and it was supposed from this attempt that skidding was most to be desired. On the other hand, at the series of trials conducted last year at Cassel, the German railway engineers started with the hypothesis that a brake-block pressure equal to only one-half the weight of the wheels upon the rail would produce the best results; while in this country the general practice has been to arrange the pressure to be slightly in excess of the weight of the wheels. For the determination of the various points at issue, the experiments to which we refer were commenced on the Brighton line in May; and, certain preliminary information having thus been gained, they were recently recommenced on a larger and more important scale, and were continued for four days. A special four-wheeled van, built by Mr. Stroudley, the locomotive superintendent of the line, was placed at the disposal of Mr. Westinghouse, who designed the whole of the apparatus employed for the purpose of measuring and recording the various facts which were to be determined. These facts were: first, the amount of friction between the brake-blocks and the wheels at various speeds; second, the force with which the brake-blocks were being pressed against the wheels, shortly described as "brake-block pressure;" and third, the retarding effect of the brakes, as shown by the strain upon the draw-bar.

The brake-blocks of the front pair of wheels of the van were suspended from the ends of two levers, which were arranged to press against the piston of a hydraulic cylinder. When the blocks were pressed against the revolving wheels, the friction between the wheels and the blocks caused the levers to turn upon their centres, and thus produced a corresponding pressure in the cylinder. This pressure was recorded by an ordinary Richards' steam-indicator, the arm of which was turned by a simple water-clock while the brakes were in action. There was also a hydraulic cylinder with an indicator to record the force with which the brake-blocks were pressed against the wheels; another to measure the strain upon the draw-bar; another to record the weight resting upon the wheels; and two of Mr. Westinghouse's speed-indicators to record separately the speed of the two pairs of wheels. Two of Mr. Stroudley's speed-indicators were also used, to facilitate the observations. The drums of all the indicators were driven by the one water-clock already mentioned, and hence the diagrams were all of the same length. Brakes were attached to operate upon both pairs of wheels when required, but in many of the experiments the blocks were only applied to the wheels which carried the recording apparatus. The van was fitted with the cylinder, reservoir, triple valve, and pipes of the Westinghouse automatic brake; and was provided with gauges and cocks by means of which the blocks could be applied with any desired degree of force. The van was drawn by the fine locomotive "Grosvenor," which also was fitted with the usual Westinghouse brake appliances, and the experiments were conducted during the course of repeated trips backwards and forward on the line between Brighton and Hastings.

The first series of experiments was directed to ascertain the exact amount of force required to skid the wheel at various rates of speed, and the retarding effect which was obtained before and after skidding occurred. When the van had attained the desired speed, the brakes were gradually applied to one pair of wheels with an increasing force until skidding was produced. At the same time with the first application of the brake the water-clock was started, and diagrams indicating the various forces and speeds were taken in the manner already referred to. These experiments were tried with the van running at speeds ranging from less than 1 mile to over 60 miles an hour. Many days will be required in order fully and carefully to work out and analyse the results shown by the very numerous diagrams which were obtained; and we can only give an approximately correct statement of some of the more important facts which were clearly demonstrated. When the van was barely moving the pressure required to skid the wheels was about equal to the weight of the braked wheels upon the rail; while at 60 miles an hour, with more than three times this amount of brake force, no skidding could be obtained, and, at 50 miles an hour, the last stated amount was barely sufficient for the purpose. Just before the occurrence of skidding, the retarding force was in many cases equal to nearly 20 per cent. of the load upon the wheels; but, as soon as the wheels were skidded, this retarding force was suddenly reduced to less than 3 per cent. at high speeds, the retarding effect of the skidded wheels gradually increasing as the the speed diminished and again reaching nearly 20 per cent. at the moment of coming to rest. The result of this series was clearly to demonstrate the necessity of the application of a very high degree of brake force when running at high speeds, and also to show that this degree of force should be gradually relaxed and diminished in proportion as the train speed itself is diminished by the pressure. It was also clearly proved that skidding must be absolutely avoided, especially at high speeds, if the best results are to be obtained.

After fully 100 experiments of this kind had been made, it was determined to enter upon a second series, in order to ascertain the practical usefulness of the knowledge which had been gained. For this purpose the brakes of the van were so arranged as to go on automatically at the moment when the van was detached from the engine by means of a slip coupling. In most of these experiments the blocks were adjusted to apply themselves to both pairs of wheels, so that the entire weight of the van might be used in stopping. Two whole days, the 24th and 25th, were occupied with these slip experiments, but it was only on the 25th that the times and distances were taken with absolute accuracy. Nine of the experiments on the 25th were made when running at 50 miles an hour, and were with various degrees of brake pressure, commencing with a degree equal to half the weight of the van upon the rails, and rising to one which produced skidding almost immediately. Two were made at about 60 miles an hour, five at about 50 miles, and two at about 30 miles; the pressure exerted being varied at each stop. For the purpose of reducing the brake power as the speed slackened, a pressure-reducing valve was put in connection with the brake cylinder by M. Westinghouse, and was so arranged that the brake might be used either with the valve or without. The practical value of this valve was very clearly shown in experiments 18 and 19, both of which were conducted upon level rails.

In experiment 18, with a speed of 50 miles an hour and a constant brake-pressure equal to 156 per cent. of the weight of the van upon the rails, both pairs of wheels were skidded in 1 and 1½ seconds respectively, or as soon as the speed was reduced to 46 miles per hour; 27 seconds and 308 yards were required to make the stop.

In experiment 19, with the reducing valve open, and with a maximum brake-pressure of 144 per cent., skidding of the hinder pair of wheels was altogether avoided, and skidding of the leading pair, to which the recording apparatus was applied, did not occur until the speed had been reduced from 50 to 42½ miles an hour. Only 15¾ seconds and only 180 yards were required to make the stop.

In experiment 17, the pressure was 164 per cent., and caused the skidding of both pairs of wheels almost instantly. The speed was 50 miles; and 315 yards and 27¼ seconds were required to stop the van; while in No. 21, in which the brake-pressure, originally of 102 per cent., was kept below the skidding point by the reducing valve, the van was stopped in 149 yards and in 11¾ seconds. In other words, when the wheels were skidded all the time, nearly twice the distance was required to effect a stop from a speed of 50 miles an hour that was required when the pressure was kept just short of the skidding point. In the last-mentioned experiments, as in the two preceding ones, the van was running on level rails. In all, the brake apparatus was so arranged as to give an almost instantaneous application of the maximum force; and, although this force was sometimes very great, no inconvenience or shock was felt by any of the occupants of the van until skidding was produced, while in all cases the stops were remarkably smooth.

Seven experiments were made with wrought-iron brake-blocks in order to determine their comparative merits. The friction appeared to be about the same as that produced by cast-iron blocks; but the tires were torn, and great sparks of fire were thrown up while the wrought-iron blocks were in action. At the moment of skidding with wrought iron, the shock was tremendous and even dangerous.

On examination of the blocks, it appeared that their grip upon the wheels had torn small pieces out of the treads, and had stopped the rotation much more suddenly than cast-iron blocks would have done. The wrought blocks, in a very short time, wore and roughened the tires perceptibly; while the action of cast blocks left the tires quite smooth.

The experiments above described have therefore sufficed to determine the relative values of skidded and of merely retarded wheels as means of stopping a train, and also to determine the relative merits of cast and of wrought iron as materials for brake-blocks. It will be easy to ascertain, by a further series, whether the powers of the various continuous brakes now in use are sufficient to produce good results; and it is proposed by Captain Douglas Galton, who has taken up the question as one of scientific mechanics, to institute trials of the several brakes now before the public, and to use the experimental van for the purpose of accurately recording the results. If the co-operation of the various railway companies can be obtained, the suggestion is to fit the cylinders and pipes of the different continuous brakes to the van, and to arrange the levers to exert the same force that will be exerted by the brake-blocks on the other wheels of the train. The van will be placed successively in front, in the middle, and at the rear of the train; and the recording apparatus will be started by electricity at the moment of the application of the brakes. In this manner correct diagrams will be obtained, recording the amount of brake power, the length of time required to bring the full amount of this power to bear, the actual speed of the train at all points during the stop, and the rate of retardation. The experiments would be tried also under three conditions—1. With the brake-blocks properly adjusted for prompt action, as in a train in perfect order. 2. With each brake-block half an inch from its wheel, as in trains in ordinary condition. And, finally, with each block three-quarters of an inch from its wheel, as in trains in bad condition. A fourth series of trials is also contemplated, in order to show, even to the most casual observer, the relative values in action of different continuous brakes. It is proposed to run competing trains side by side, on parallel lines, and to apply the brakes to each at the same moment. The conditions will necessarily be the same for each, and the respective merits most at once declare themselves.

It is to be regretted that Captain Galton and Mr. Westinghouse did not avail themselves of the opportunities afforded by their slip experiments to arrange the brakes in such a manner that their maximum force should be applied to the wheels first in one second of time, then in two seconds, then in three, and so on until the period of 12 seconds had been reached, that being the time which is required by some of the continuous brakes now in use before they can be brought to bear over the whole length of a train. The whole of the experiments so far have been conducted with the Westinghouse automatic brake, and they have shown its power to any pressure which may be required, and also to give instantly a very high pressure, which is capable of being gradually reduced, when necessary, by the action of the reducing valve.—*The* (*London*) *Times.*

Internal Heat of Rocks.—Daubrée reports some experiments upon the heat which may be developed by mechanical action in the interior of rocks, especially in clays, and applies his results to the theory of metamorphism. He finds that the heat increases much more rapidly when the mass is tenacious than when it is plastic, the particles in the latter case being, as it were, lubricated and slipping over one another. The experiments may, perhaps, also have an important bearing upon Mallet's theory of earthquakes and volcanoes. —*Comptes Rendus.* C.

Variations of Weight.—Plantamour has made a recent communication to the French Academy, upon the changes which are observed in the directions of vertical lines at any given place. Similar observations have been previously made by Bouquet de la Grye, with the seismograph, and by d'Abbadie, with the aid of the "nadirane." The latter thinks that the variations of the plumb-line can result only from two causes: either from a change of position in the earth's centre of gravity, or from a movement of the superficial layers of the ground. It seems likely, however, that a variety of influences may be at work, some acting vertically, some tangentially, and some in intermediate directions. In order to study the phenomena properly, it is necessary to combine the aberrations of the seismograph and of the "nadirane" with a continuous registry of the intensity of the weight.—*Les Mondes.* C.

Almaden Mines.—The amount of quicksilver which has been yielded by the Almaden mines during the past three centuries, is 120,179·6 tons, viz.: From 1564 to 1700, 17,863·72 tons; from 1700 to 1800, 42,149·501 tons; and from 1800 to 1875, 60,166·379 tons. At the rate of 12 fr. per kilogramme, the total value would be 1,440,000,000 fr.—*Ann. des Mines.* C.

Nitrification by Organized Ferments.—Schlösing and Muntz conclude, from an extended series of observations, that the vegetable organisms of a low order, such as moulds and mycoderms, which lead to the slow combustion of organic matter, do not produce nitrification. On the contrary, they transform the nitric acid, at first, into organic matter; then, at least in part, into free nitrogen; the latter phenomenon being often accompanied with the production of ammonia. Consequently, they occasion a diminution of the combined nitrogen which exists upon the surface of the globe. When the nitrogen is present, under both forms, in a soil, the mycodermic vegetable which is developed there assimilates in the largest proportion the ammoniacal nitrogen.—*Comptes Rendus.* C.

British Ceramics.—In some complimentary remarks upon the British display of ceramics at the Paris Exposition, *Les Mondes* calls attention to "the brilliant specialties of the factory at Worcester, the English Sevres." The imitations of ivory are said to be so perfect as to deceive the eye, and require the testimony of the touch in order to detect the deception. Among the statuettes are some Chinese figures, which one would judge to be chiseled in ivory by the most skilful sculptor of the Celestial Empire. By their side are imitations of Japanese jade, with its semi-transparency, its elegant intaglios of flowers and birds, which are imitated to perfection. A little farther on are admirable representations of the old enamels of Limoges, with their lively painting, which are in white relief on a dark blue ground. In other places there are turquoises, which are embossed in relief, or ornaments of gold, so skilfully reproduced by means of the enamel, that one may well ask whether jewelry could do better. "It is evident to everyone that M. Binns, the present director of the Royal Factory at Worcester, has made a special study of Japanese art, and that he has introduced into its fabrication many of the ornamental suggestions created by the industrial artists of the extreme East." C.

Spectrum of Gun Cotton.—Vogel (*Annalen der Physik*, 1878, Bd. iii, S. 615) shows that the spectrum of exploding gun-cotton, which was observed by Lohse, is identical with the spectrum of calcium chloride. Numerous samples of pyroxylin, which were examined by Vogel, contained lime, which may have been easily introduced by the water employed in washing out the acids. C.

Imperfections of the Telephone.—Serpieri and Cappanera have studied the sounds which are only imperfectly transmitted by the telephone, and find a frequent confusion of the following sounds: *e*, *a; tr*, *cr*, *dr*, *pr*, *fr; n*, *m; s*, *f; et*, *el; eb*, *eu; d*, *t; ic*, *ip; dra*, *tra*, *gra; te*, *chi; at*, *ai; i*, *u; l*, *r; o*, *e; v*, *b*.—*Ding. Polyt. Jour.* C.

Sonorousness of Alloys.—Lilliman communicates a ringing elasticity to certain alloys of tin and other soft metals, with copper, antimony, etc., by plunging them for a short time in a bath of paraffine or oil, heated nearly to the boiling temperature. This operation, which produces a crystallization, slightly diminishes the density; it increases the hardness and rigidity.—*Pol. Notizbl.* C.

A New Element.—J. L. Soret, in following out some recent investigations of Marignac, finds conclusive evidence of the existence of terbine in gadolinite, although its existence has been doubted by Bahr and Bansen, as well as by Cléve and Hoglund. He also confirms Marignac's opinion that there is a fourth earth in the same mineral, resembling terbine in its yellow color, but having a smaller atomic weight. The ultra-violet spectrum of this fourth earth gives lines which have not been hitherto observed, and which are strongly indicative of a new element.—*Comptes Rendus.* C.

Terrestrial Influence on Polarization of Light.—In the course of his researches on rotary magnetic polarization, Henri Becquerel has been led to the direct estimate of the action of terrestrial magnetism upon different bodies. In the course of these experiments he has found that if a tube, containing bisulphide of carbon, is placed between a polarizer and an analyzer, in the plane of the magnetic meridian, there is an angular difference of 6·5′ between the two positions of the plane of polarization when looking towards the south or towards the north. This difference he attributes to terrestrial action.—*Comptes Rendus.* C.

Cobalt Plating.—Gaiffe had his attention called to the beauty and durability of cobalt, when deposited by the galvanic battery, and endeavored to utilize it as a substitute for iron and nickel, especially in electrotyping. It does not rust like iron, so that the surface can be easily preserved in good condition, and it is easily dissolved by weak acids, which do not attack the copper, whilst the nickel cannot be removed from a copper plate without injuring it. The beautiful whiteness of the cobalt makes it valuable for the decoration of other metals. He recommends a bath of a neutral solution of the double sulphate of cobalt and ammonia, which requires, in its preparation, about as much care as the nickel baths. The anode may be a leaf of platinum, or a plate of cast or forged cobalt. In order to obtain an adherent and white deposit, a current of about six units of electromotive force [Brit. Assoc.] should be employed at the beginning, and it should be reduced to about three units when the whole surface has become white. With a suitable intensity of current, the cobalt deposit is made nearly as rapidly as that of nickel. In four hours the coating may obtain the thickness of ·025 mm. If a very regular deposit is desired, the piece which is to be plated should be attached to the rheophore of the pile before plunging it in the bath.—*Comptes Rendus.* C.

Luminous and Chromatic Sensations.—Aug. Charpentier and Dr. Landolt have found that the sensations of light and of color are the results of two entirely distinct functions, which, although they are intimately blended in the habitual use of the vision, may be clearly distinguished from each other by physiological analysis. By experiments with lenses, they found that the sensibility of the eye to light was much greater when the eye is at rest in darkness than when it is in activity. There was, however, no such difference noticeable in the sensibility to color. Charpentier thinks that the explanation of this fact is to be found in the discovery by Boll and Rühne of a reddish chemical substance in the retina, which is discolored by light and which is renewed in darkness. If we admit, as seems probable, that the optic nerve is excited not directly, by light, but indirectly, by the chemical modification which the light produces in the retinal red, the superior sensibility of the eye in repose may be explained by the excess of the photo-chemical substance which the eye has acquired under the influence of darkness.—*Comptes Rendus.* C.

Terrestrial Constants.—J. B. Listing (Göttinger Gesellschaft der Wissenschaften) gives the following summary of the latest estimates of important geometric and dynamic constants: Major axis of the rotation ellipsoid, which most nearly represents the form of the earth, 6,377,377 metres; minor axis, 6,355,270 m.; radius of the earth, regarded as a sphere, 6,370,000 m.; length of the seconds pendulum at the equator, 0·9909948; ditto, lat. 45°, 0·9935721; ditto at pole, 0·9961495; g. at equator, 9·780728; ditto, lat. 45°, 9·806165; ditto at pole, 9·831603; centrifugal force at the Equator, due to the rotation of the earth, 0·0339117. C.

Agricultural Use of Electricity.—Berthelot commends Grandeau's remarks upon the "influence of atmospheric electricity upon the nutrition of plants," referring especially to his discovery that the proportion of nitrogenous matter, which is formed under that influence in tobacco and maize, is twice the proportion which is found in the same plants when withdrawn from the influence of atmospheric electricity; the total growth of the plant being proportional to the nitrogenous matter. He also calls attention to some of his own investigations, especially to the fact that free nitrogen is accumulated by organic matters, not only by employing the strong intermittent tensions of ordinary induction apparatus, but also with very feeble and continuous tensions, and especially by employing atmospheric electricity. In some of his experiments, microscopic vegetables appeared which absorbed an additional amount of nitrogen. Before his researches were undertaken, it was generally supposed that nitric and nitrous acids and their ammoniacal salts were produced only by the electricity of heavy thunder showers. It is now evident that the reactions between vegetables and the atmosphere, under feeble electric tensions, are the most important, the smallness of the effects being compensated by their duration, and by the extent of the surfaces influenced.—*Comptes Rendus.* C.

A New Method for Cutting Rails of Uniform Length.—Attention has been called by Dr. Kollman, of the Berlin School of Mines, to a method of photometric determination of temperature which is used in Russian rolling mills to ascertain the exact lengths into which rails must be cut when at a low red. Ordinarily the rails are allowed to cool down to a dull red, which is estimated, and are then cut by accurate mechanical means. It was found, however, that their lengths varied considerably, because the temperature at which the rails had been cut differed, and therefore they did not contract evenly. If, however, the hot rails are looked at through colored glass, the color and tint may be so chosen that when the rail has arrived at a certain temperature it becomes invisible to the eye, this being the time when it is to be cut. Blue or orange glass is best adapted for this purpose. In order to obtain good results, the observations should always be made from the same distance.—*Metallurgical Review.* *

The Phonograph Diaphragm.—Dr. Clarence Blake, of Boston, in his experiments with the phonograph, was led to believe that a diaphragm, shaped like the drum membrane of the human ear, might give improved phonographic utterance. He arrived at this conclusion from finding that flat disks gave too great a prominence to certain heavier overtones of the voice to which they respond, and hence falsified the *timbre* of the voice in reproducing it. By forming the phonograph diaphragm into a flat trumpet-shape (with a funnel section) and fixing the embossing style into the cusp, it was found that the lighter overtones were faithfully reproduced by it, while the sharper exaggerated overtones recorded by the flat disk were cut off. When the embossing, as well as the reproducing, was done by this curved membrane, the sharper overtones disappeared, and the quality of the voice was much more natural. Moreover, there was a gain in sensitiveness ; the embossing could be done at a distance of 15 feet from the speaker, and clearly reproduced. The material of these membranes may be either stout felted paper, varnished on its outer surface, or drum-vellum, moistened and modeled into shape before using. "The principle governing the vibrations of such a disk," says Dr. Blake, "is that of imparting the vibrations to the centre of a membrane, the curve of which enables it to reproduce a large range of overtones, its tension serving as a counter-balance to the central pressure." Dr. Blake has also found that the groove in the phonograph cylinder, when covered with tinfoil, became a resonator for the high scratching noise of the embossing point, and materially interfered with the reproduction of the quality of the voice. By stretching a thin layer of rubber tissue over the cylinder, this resonating effect was abolished, and the scratching noise materially lessened. —*Telegraphic Journal.* *

Stethoscopic Microphone.—M. Ducretet, says the *Telegraphic Journal*, has applied the pneumatic tube vibration-transmitter employed by M. Marey in physiological experiments, to the microphone. This consists of a flexible india-rubber pipe connecting two small drums, or closed air-chambers with convex lens-shaped membranes, so that when one of the membranes is pressed against the pulse, the other membrane will pulsate the air-transmitted air-vibrations. M. Ducretet makes use of it by resting one of the lens-shaped membranes upon the upper contact of a pencil microphone, leaving the other drum free to be applied to the pulse, the lungs, heart, or other organ of the body. This has been called the *stethoscopic* microphone.

An arrangement similar to this was exhibited at the meeting of the Franklin Institute, on June 19th last, by Mr. A. E. Outerbridge, but with the advantage of the microphone being attached direct to one of the membranes. *

Discovery of the Planet Vulcan.—Prof. J. C. Watson, of Ann Arbor, under date of August 2d last, sends to Rear Admiral Rogers, Supt. of the Naval Observatory, the following report of his observations during the total eclipse of the sun, on July 29th, of what he believes to be the long talked of planet between Mercury and the Sun:

"I have the honor to report that at the time of totality, I observed a star of the four-and-a-half magnitude, in right ascension, 8 hours, 26 minutes declination, 18 degrees north, which is, I feel convinced, an intra-mercurial planet. I observed with a power of forty-five, and did not have time to change the power so as to enlarge the disk. There is no known star in the position observed, and I did not see any elongation such as ought to exist in the case of a comet very near the sun. I will hereafter report to you more fully in regard to the observations made. The appearance of the object observed, was that of a ruddy star of the four-and-a-half magnitude. The method which I adopted prevents the possibility of error from wrong circle readings; besides, I had memorized the Washington chart of the region, and no such star was marked thereon. By comparison with the neighboring stars on Argelander's scale, the magnitude of the planet would be fifth, although my direct estimate at the time of the observation was four-and-a-half, as stated." *

Temperature of Flames.—Signor F. Rosetti has made the temperature of flames the subject of a series of investigations. For this purpose he has made use of the calorimeter of his own invention. The maximum temperature of a Bunsen flame he has found to be 1360° Cent., obtained by the combustion of one volume of gas and two and one-fifth volumes of air. The admission of either a greater or less quantity of air reduces the temperature. Changes in pressure have but slight influence on the temperature. The flame given by gas diluted with its own volume of nitrogen shows a temperature of 1180°, and diluted with three volumes of nitrogen, 1040°. The same degrees of dilution with carbonic acid show, respectively, 1100° and 780°. Among other temperatures noted were the following: From Locatelli lamp, 920°; stearine candle, 940°; petroleum lamp with chimney, 1030°; the same without chimney, illuminating part, 920°; sooty envelope, 780°; alcohol lamp—alcohol, 0·912—1170°; ditto—alcohol, 0·822—1180°. The difference in the heating power of alcohol resulting from widely-differing percentages of water is considerable.—*The Engineer.* *

The Tasimeter and Magnetization.—Professors Andrew and Thomas Gray have published, in *Nature*, an account of their experiments to detect, by the use of Edison's tasimeter, the elongation and shortening produced, in a bar of iron, by magnetization and demagnetization.

A piece of stout iron-wire was placed in the instrument, in the usual manner, and surrounded by a helix, through which a battery current could be passed.

The terminal wires from the plates bearing on the carbon bottom, were joined in circuit with one Daniell's cell and a Wheatstone bridge, in which a delicate Thomson's reflecting galvanometer was employed. The pressure of the iron rod against the carbon bottom, and the resistances, were so adjusted that the galvanometer pointed to zero.

Upon passing the current from one Daniell's cell through the helix, the galvanometer needle was considerably deflected, but returned to zero when the current was broken, showing that the iron core had been lengthened by magnetization.

By replacing the comparatively rough adjusting screw of the tasimeter by a micrometer screw, they hope to determine the exact amount of elongation or shortening produced, in a piece of soft iron or steel, by given changes of magnetic intensity. *

THE TELEPHONE RELAY.

Editors JOURNAL OF THE FRANKLIN INSTITUTE:

Sirs:—Since the publication, in the JOURNAL OF THE FRANKLIN INSTITUTE, vol. cvi, 1878, of a short article on the Microphone Relay, by Prof. Thomson and myself, I have noticed two claimants for priority of invention; one in the *Telegraphic Journal* of London, of July 1st, and the other in the *Chemical News*, of July 26th.

The writer in the *Telegraphic Journal*, after briefly commenting on the claim of Prof. Thomson and myself, to the invention of the Microphone Relay, as contained in a short note to *Nature*, of June 20th, remarks as follows: "This application was pointed out, as we reported in our last number, by Prof. Hughes, at a meeting of the Physical Society, on June 17th." The writer could scarcely have given careful attention to our note to *Nature*, or he would have seen that it was dated Philadelphia, June 7th, and therefore clearly anticipated the application pointed out by Prof. Hughes, on June 17th. As you are aware, we exhibited a successful working model of our relay at the Institute and elsewhere, on June 4th, accounts of which were published in the papers of this city on the following day.

The writer in the *Chemical News*, of July 26th, is Mr. Edison, of New Jersey, who claims priority of invention by more than a whole year. Though I have been informed by others that Mr. Edison made this claim, yet, so far as I am aware, this is the first time the gentleman has made the claim over his signature, and I therefore take the present opportunity of answering it. In his letter to the *Chemical News*, Mr. Edison employs the following unequivocal language, viz.: "Allow me to state that *the telephonic repeater described by Messrs. Houston and Thomson* in your issue of June 21st, was invented by me over a year ago, and *one of the many* forms devised by me was published in the *Journal of the Telegraph*, July 15th, 1877, and in the *Telegraphic Journal*, of London, about the same date." (The italics are my own.) Here it would appear that Mr. Edison claims the particular form of repeater described by Prof. Thomson and myself. Now, whatever Mr. Edison may have accomplished in this direction prior to the announcement of our invention, he can only claim what he has published. It will not do for him to claim many (any) forms. In his letter, he alludes to but one, viz.: that published in the *Telegraphic Journal*, of July 1st, 1877. I have carefully read his article, and find it to be a description of a "Pressure relay" for his speaking telegraph. This speaking telegraph, so far as I have been able to ascertain, *is not a telephone*, but a species of harmonic telegraph, similar to that of Gray, and the invention was for the purpose of repeating the vibratory pulses employed in that system. Mr. Edison nowhere, that I can find, claims, prior to our announcement, that this relay was applicable to the *articulating telephone*, and it would appear very improbable that had he been aware of the fact, he would have failed to have given it publication. It would seem to me that since the invention of Prof. Thomson and myself consists in an application of Prof. Hughes' microphone to the Bell articulating telephone, that before Mr. Edison can establish his claim to our telephone relay, he must substantiate his claim to the invention of the microphone, and this, it would appear, he has as yet failed to do. Respectfully Yours,

EDWIN J. HOUSTON.

CENTRAL HIGH SCHOOL,
Phila., August 22d, 1878.

Book Notices.

REPORTS AND AWARDS OF THE INTERNATIONAL EXHIBITION, 1876. Group XX, Motors, Hydraulic and Pneumatic Apparatus, &c., 8vo, pp. 424. Price, $2.00. J. B. Lippincott & Co.

The exhibits embraced in the group are mostly such as the members of the Institute are largely interested in, and considerable space has been devoted to their discussion in the JOURNAL, and, therefore, the report may be allowed more than usual attention.

While great weight may be placed upon the opinions of the judges, based upon a mere examination of the various exhibits, together with their past experience; yet in such a group as this, by far the most valuable information is to be derived from careful and scientifically conducted tests. In this instance, such tests of the steam boilers, water-wheels and steam fire-engines were instituted, and thoroughly carried out by experts, especially fitted for the work.

The method employed and the manner of conducting the boiler tests, together with a table of the more important results, have already been given in the JOURNAL,[1] and, therefore, need not be expected here. In addition to this, the general report contains an article by Mr. Charles E. Emery, one of the judges upon "Boiler Proportions," in which he says: "The experiments do not indicate that mere peculiarty of arrangement of mechanical details affects, to any material degree, the comparative efficiency of boilers. * * * *

---

[1] See vol. civ. page 105.

"It is believed that a boiler with any kind of mechanical details and arrangements, not absolutely faulty, can be proportioned to give the same evaporative efficiency as one of any other form."

Diagrams are given comparing graphically the results of the Centennial boiler tests with each other, and also with those obtained by other experimenters, notably those of Chief Engineer B. F. Isherwood, United States Navy, during the years 1858 to 1866.

These diagrams also throw additional light on the question as to how far mere evaporative economy should control the size of boilers for a desired service, and the writer very properly says: "The conditions of each particular case must determine the question whether a saving of fuel, with increased first cost, is of greater importance than an original saving in cost of construction, * * * * first cost can be increased till the saving in fuel equals the interest." * *

Both these views have been widely, if not generally, adopted by engineers, but this additional evidence of their truth is very acceptable.

The committee on boiler tests state, however, "that the award of the judges were not based upon the trials; in fact the latter were not commenced until the awards had been made by another committee of the same group."

The exhibits of turbine water-wheels were very numerous. The report of Mr. Samuel Webber, superintending engineer of Centennial turbine tests, together with records and drawings of the various wheels tested, is given, but without comment by the judges, except a few commendatory remarks by Mr. W. H. Barlow, on page 122, taken from the report of the British Commissioner. This was also reviewed in the JOURNAL, from advance sheets of the Report of the Chief of the Bureau of Machinery, rendering further notice here unnecessary.

Considerable attention was given to comparative trials of steam fire-engines, and the results, as given in detail, possess much interest. In this case, as in that of the water-wheels, there is no analysis of the tabulated results, which certainly is desirable, and would have added greatly to the value of the experiments.

The trial of the Hoadley portable steam engine, recorded on pages 152–8, shows results seldom, if ever, equaled by engines of that class.[1]

There was little of novelty among the exhibits of stationary steam engines, and that part of the general report devoted to them is limited to a mere description of the more prominent ones. There is an article, by Chas. E. Emery, on "Steam Engine Economy," based, however, entirely upon the performance of engines other than those on exhibition.

---

[1] In the course of his preparations for these tests, Mr. Hoadley made other experiments, a portion of which appear in the following valuable papers, published in the JOURNAL: "Radiation from Steam Boilers," vol. ciii, page 233, and "The Curve of Compression," vol. cv, page 1.

An outline is given of the "American" system of transmission of power, including the substitution of belting for large gear-wheels between the motor and the lines of shafting, and also the American shafting, as introduced, by Messrs. Wm. Sellers & Co., twenty years ago, and now generally adopted in this country. As an example of the extent to which belt transmission is employed here, mention is made of a leather belt on exhibition, made to order, which is 5 ft. wide, 186½ ft. long, and weighing 2212 lbs., the largest belt ever constructed.

There was a large display of hydraulic exhibits, although presenting few novel features. The article on "Pumping Engines" contains a comparison of the performance of some of the well-known designs, and a short historical sketch of the progress of improvement of this class of machines in the United States.

Under the head of "Steam Boiler Inspection," there is given an interesting account of the workings of the Manchester (England) Steam Users' Association, by Mr. L. E. Fletcher, the Chief Engineer, and which is worthy of the attention of steam users everywhere. *

OUTLINES OF NATURAL PHILOSOPHY. By Prof. E. J. Houston. 12mo, pp. 123. Philadelphia; Claxton, Remsen & Haffelfinger. 1878.

This little book is intended especially for young children, and the author has been at great pains to bring the elementary principles of natural philosophy within their comprehension, by the use of simple language, in explaining things common to the experience of everyday life.

Children often acquire false notions of natural laws, by attempts to teach them things beyond their powers to grasp, and to prevent this there is a wise omission of all topics which, from their nature, do not admit of a thorough explanation in language adapted to those for whom the book is designed.

Evidently aware of the importance of enlisting the sympathies of children in their studies, Prof. Houston has, to a large extent, drawn his illustrations from things connected with their pleasures, thus forming an association of ideas more likely to be lasting.

The book is in the usual style, of question and answer following each other in a natural and easy sequence.

The eagerness with which it was read by several boys of suitable ages, into whose hands it accidentally fell, proved its adaptability to their wants. *

MEMOIR OF B. H. MOORE.

Bloomfield Haines Moore was born in the City of Philadelphia, December 16th, 1819.

His parents, Samuel French Moore and Rachel Matlack Moore (whose maiden name was Haines), were members of the religious Society of Friends, and were natives of New Jersey.

The paternal ancestor of the fifth preceding generation, John Moore, emigrated from his home in Lincolnshire, Eng., in 1677. His family was a branch of the Devonshire Moores, now extinct in England.

The Harvard class history of the son of Mr. Bloomfield H. Moore, mentions the fact that the family bible, brought from England by one of his paternal ancestors, is of the edition of 1616, printed in London; and that the family bible of his mother's family is "the Geneva version of 1599, much valued on account of its notes." Both of these ancestors belonged to the Society of Friends, and left England on account of religious persecution, following William Penn to this country, after first sending a commissioner, who purchased tracts of land (for them and their connections) in New Jersey, Pennsylvania, and Massachusetts.

During the latter part of the last century, the descendants of John and Benjamin Moore were notified, first by advertisements in Trenton and Philadelphia newspapers, and afterwards by letters from a solicitor in London, that they were heirs to an estate in England, amounting to some millions of pounds sterling. The answer, sent back by Joseph Moore, who represented the family on this occasion, was that they had enough of this world's goods, and were contented with their situation in life. As this property was left to them by a will registered in Doctors' Commons in London, an effort was made, early in this century, by one of the descendants, to recover the estate, but, as the house of Joseph Moore had been burned in the meantime, with all its contents, including the family papers, the attempt was abandoned, as involving too much expense.

The descendants of John Moore, in western New Jersey, were large landed proprietors, and lived upon their property down to the time of Mr. B. H. Moore's grandfather, Amasa Moore, who married Agnes French. Bethuel Moore, the father of Amasa, survived his son twenty-one years, and, although the wealthiest man in Burlington County, he had the good sense to choose trades for his orphan grandchildren, the three sons of Amasa Moore. It was he, also, who furnished the capital with which they went into business for themselves, after they had learned their trades. He died March 4th, 1831, aged 89.

A friend of the family, the late Jacob Ridgway, befriended the young architects and builders, and did all that was in his power to throw business into their hands.

Samuel French Moore, the father of the subject of this sketch, and grandson of Bethuel Moore. was a man of such marked ability, that Mr. Ridgway encouraged him to go into the real estate business. Success attended whatever he touched, but he died at the early age of 30, leaving his two children to the guardianship of Mr. Ridgway, who also administered their father's estate.

Mr. Samuel F. Moore's widow continued to reside in the house built for her by her husband, until her death, which took place May 19th, 1851. The house, which is still owned by her son, Carlton Ridgway Moore, now living in Virginia. is situated on Carlton Square, in a street named after Lady Callowhill, a relative of William Penn. Carlton Sqnare was in a pleasant suburb of our city (surrounded, as it was, by old country seats) at the time the site was chosen by a small colony of Quaker families; but at the present time this street is principally occupied by shops and dwellings of an inferior character, with the exception of this one block of now venerable houses in Carlton Square, and the newer residences opposite.

The maternal ancestor of Mr. Moore, Richard Haynes, after his imprisonment in England for being a Quaker, emigrated to America, to escape religious persecution. The homestead, for which a patent was granted at Evesham, N. J., in 1683, is still in possession of the Haines family, who have changed the *y* into an *i* in their name. George Haines, who died at the age of 79, April 13th, 1877, was one of the oldest physicians in New Jersey. He was the brother of Mr. Moore's mother.

The early education of Mr. Moore was conducted at the well-known Friends' School of Isaac Taylor and Thomas Conrad, where he was prepared for passing examination at Princeton College, according to the wish of his father; but objections being raised by a member of the family of his guardian, and a course of study at Clermont Academy[1] advised, the sons of Samuel French Moore finished their school education at this academy, which bore a high reputation in its day.

---

[1] Formerly a Military School.

Bloomfield H. Moore then entered the office of Mr. Ridgway, in which he remained until he went into business for himself. In October, 1842, Mr. Moore was married to Clara, only daughter of Augustus E. Jessup, of Western Massachusetts; and in 1843, Mr. Moore gave up the business in which he had invested a legacy of $10,000, left to him by his guardian, and entered into partnership with his father-in-law, Augustus E. Jessup, under the firm name of Jessup & Moore, dealing in paper and paper stock.

In 1845, the firm of Jessup & Moore enlarged their business by commencing the manufacture of paper on the Brandywine. Mr. Jessup, as a scientist, had, many years before, made experiments for improving the manufacture of paper, and in consequence of his success in these experiments, he had established his well-known paper-mill in Westfield, Mass., where he made bank-note paper, holding large contracts with the United States Government for its manufacture. This mill he disposed of to his brothers when he removed to Philadelphia. Mr. Moore invested in this (to him) new business (the manufacture of paper), not only the profits of his previous business, but also the money that he inherited from his great-grandfather and his father. In addition to the united capital of the firm, Mr. Alfred Dupont, the classmate and life-long friend of Mr. Jessup, advanced nearly fifty thousand dollars for enlarging the business, refusing to take from Mr. Jessup any mortgage, note, bond, or evidence of debt whatever, from the time of lending the money to the time of its return.

The original paper-mill of Messrs. Jessup & Moore, now known as the Augustine Mill, has since been greatly enlarged by Mr. Moore, and is probably not excelled by any in the world for perfect adaptation to the work. Subsequently the firm erected paper-mills at Rockland and near Coatesville, and have, for years, been the largest manufacturers of paper in this country.

Although actively engaged in a business which required close attention, rendered the more necessary by its rapid development, Mr. Moore found time for reading and for pursuits which were congenial to his taste, and for the accumulation of a very valuable library. Political economy and social science were branches to which he devoted considerable attention; several monographs from his pen were published on occasions of public interest.

Mr. Moore became a member of the Franklin Institute in March, 1863, and was elected to its Board of Managers in 1864, and served as a manager until 1877.

In 1869, he was elected one of the vice-presidents of the Institute, and served eight years. From 1864 to 1874, he was one of the curators; and from 1867 to 1877, a member of the Committee on Publication, and during most of the time was chairman of the committee. For ten years he served on the Committee on the Library, and for nine years on the Committee on Exhibition. At the close of the year 1876, his family urging some relief for him from engagements outside of his business, he declined re-election to any official position in the Institute.

Mr. Moore died at his residence, South Broad Street, Philadelphia, July 5th, 1878, from acute pneumonia, which supervened an attack of pleurisy. His illness was of one week only.

Endowed by nature with a well-balanced mind, Mr. Moore was well calculated for the successful prosecution of whatever he undertook. Careful, without unnecessary timidity, he was always ready to appreciate and take advantage of whatever tended to advance manufacturing skill in his department.

In his business relations he was affable, obliging, just, and careful to avoid offense; possessing qualities valued in social intercourse, he was an intelligent and agreeable companion, and he leaves a large circle of friends, who unite with his family in mourning his loss while in the meridian of his strength and usefulness.

Franklin Institute.

DONATIONS TO THE LIBRARY.

Bulletin of the Society of Encouragement, etc., Paris, for Oct., 1855; Feb. and Oct., 1856; Feb., 1858; Oct., 1862; Aug., 1863; May, June and July, 1868; Feb., Mar., June and July, 1874.
From the Librarian of the Society.

Report upon United States Geographical Surveys, west of the one hundredth meridian, in charge of Lieut. Geo. M. Wheeler. Vol. 2. Astronomy and barometric hypsometry. Washington, 1877.
From the Chief of Engineers.

Naturalists' Agency Catalogue. Part 1. Minerals. A. E. Foote. Philadelphia, 1876.

Kinetic Theories of Gravitation. By W. B. Taylor. Washington, 1877.
From the Secretary.

Quarterly Report of the Chief of the Bureau of Statistics. Treas. Dept., for the three months ended Dec. 31st, 1877.
From the Bureau.

Argentine Republic, written in German. By R. Napp, for the Central Argentine Commission, on the Centenary Exhibition at Philadelphia. Buenos Ayres, 1876. From the Smithsonian Institute.

Transactions of the Society of Engineers for 1875. London, 1876.
From the Society.

Proceedings of the 18th to 23d, and 25th and 26th, annual meetings of the Board of Supervising Inspectors of Steam Vessels, 1870-'78. From E. F. McGill, Philadelphia.

Report of the Commissioner of Education for 1876. Washington, 1878. From the Commissioner.

Eleventh report of the Peabody Institute of Baltimore, June 1st, 1878. From the Institute.

Circular of information and annual report of the Board of Visitors and Superintendent of the Kentucky Military Institute, for the year ending June 6th, 1878. From the Institute.

Geological survey of Canada, report of progress for 1876–77.
From the Director.

Catalogue of the American Philosophical Society Library. Part 3. Philadelphia, 1878. From the Society.

Specifications and drawings of patents, issued from the United States Patent Office, for December, 1877, and January, 1878.
From the Patent Office.

Treatise on files and rasps. From the Nicholson File Co., Providence, R. I.

Instructions for observing the total solar eclipse of July 29th, 1878. From the U. S. Naval Observatory.

Anales de la Oficina Meteorológica Argentina. Tome 1, 1878.
From B. A. Gould, Director.

Nature of Physical Forces. By E. Vogel.
From the Author.

Annual report of the New York Meteorological Observatory, for 1877. From the Director.

Twenty-second report of the Board of Trustees of the Water Works of Cleveland, 1877. From the Trustees.

Catalogue of bolts, nuts, etc. From Hoopes & Townsend.

Quarterly report of the Chief of Bureau of Statistics, March 31st, 1878. Washington. From the Bureau.

Annual report of the Commissioner of Fairmount Park, Philadelphia, 1878. From the Commissioners.

Post route map of the States of Pennsylvania, New Jersey, Delaware and Maryland, etc.
From the Post Office Department, Washington.

Dyer and Color Makers' Companion, Philadelphia, 1850.

Book of Chess, containing the rudiments of the game, by H. R. Agnel. From D. S. Holman.

Twenty-sixth annual report of the Trustees of the Public Library, 1878. From the Trustees.

Memoirs of the Geological Survey of India. Palæontologica Indica, Ser. 2, No. 3; Ser. 4, No. 2; Ser. 10, No. 3; Ser. 11, No. 2. From the Geological Survey Office, Calcutta.

Forty-fifth annual report of the Royal Cornwall Polytechnic Society, 1877. From the Society.

Report of the New Jersey State Commissioner appointed to devise a plan for the encouragement of manufactures of ornamental and textile fabrics, 1878. Trenton. From the Commissioner.

Verhandlungen des Naturhistorisch-Medicinischen Vereins zu Heidelberg. Neue folge, zweiter bund 1878. From the Union.

Annual report of the Secretary of the American Iron and Steel Association. Philadelphia, July 15th, 1878.
From the Association.

Researches on the motion of the moon, made at the United States Naval Observatory, by Simon Newcomb. Washington, 1878.
From the Observatory.

Anales del Instituto y Observatorio de Marina de San Fernando. Seccion 2ª Observaciones Meteorológicas, Año, 1875 and '76. San Fernando, 1877. From the Observatory.

Journal of the Royal Geographical Society, Vol. 47, 1877, London. From the Society.

Ahiman Rezon, abridged and digested as a help to all that are or would be free and accepted Masons. Philadelphia, 1873.
From E. Hiltebrand.

Annual report of the Chief Signal Officer to the Secretary of War, for 1877. Washington. From the Chief Signal Officer.

Pettingill's Newspaper Directory and Advertisers' Handbook, for 1878. New York. From S. M. Pettingill & Co.

A Familiar Compend of Geology, by A. M. Hillside, Philadelphia, 1859. From D. S. Holman.

Fourth annual message of W. S. Stokley, Mayor of Philadelphia, September 18th, 1876. From the Mayor.

1st to 3d Conferencias Celebradas na Academia Real das Sciencias de Lisboa 1877.

Sessao publica da Academia Real das Sciencias de Lisboa. Em 12 de Dezembro 1875 and Em 15 de Maio de 1877. 2 vols.

Historia dos Estabelecimentos Scientificos Litterarios e Artisticos de Portugal por José Silvestre Ribeiro. Vols. 1–6. Lisboa, 1871–1876.

Journal de Sciencias Mathematicas Physicas e Naturaes da Academia Real das Sciencias de Lisboa. Vols. 1–5. Lisboa, 1868-1876.

Historia de Congo obra posthuma de Visconde de Paiva Manso. Lisboa, 1877.

Chimica Agricola ou estudo Analytico dos Terrenos, das plantas, etc., por J. I. F. Lapa. Lisboa, 1875.

Memorias di Academia Real das Sciencias de Lisboa. Novo Ser. Tome 5, Part 1, Lisboa, 1875.

Historia e Memorias da Academia. Novo Ser., Tomo 4, Parts 1 and 2. Lisboa, 1872 and 1877.
From the Royal Academy of Lisboa.

The above donations to the Library were reported at the meetings of the Board of Managers held July 10th and August 14th last.

J. B. Knight, *Secretary.*

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CVI. OCTOBER, 1878. No. 4.

THE Franklin Institute is not responsible, as a body, for the statements and opinions advanced by contributors to the JOURNAL.

THE TOTAL SOLAR ECLIPSE OF JULY 29TH, 1878.

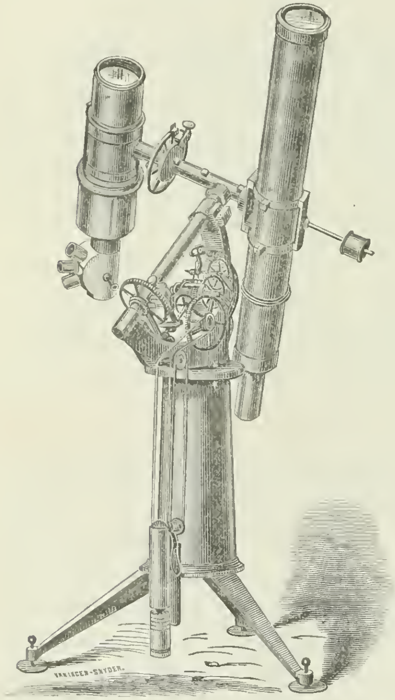
By Prof. HENRY DRAPER, M. D.

As the eclipse of July 29th occurred at a time when there were no sun spots and the chromosphere was in a condition of minimum activity, it seemed probable that new facts concerning the corona might be ascertained. For this reason I organized an expedition, consisting of my wife and myself, my friends, Profs. Morton and Barker, and Mr. Edison. Rawlins, Wyoming Territory, was selected as the station for a temporary observatory, because, while it was near the central line of totality, it was supplied with water from the granite of Cherokee Mountain, which facilitated photographic operations, and was in a region that was dry and apt to be cloudless. Being on the line of the Union Pacific R. R., apparatus could be easily transported.

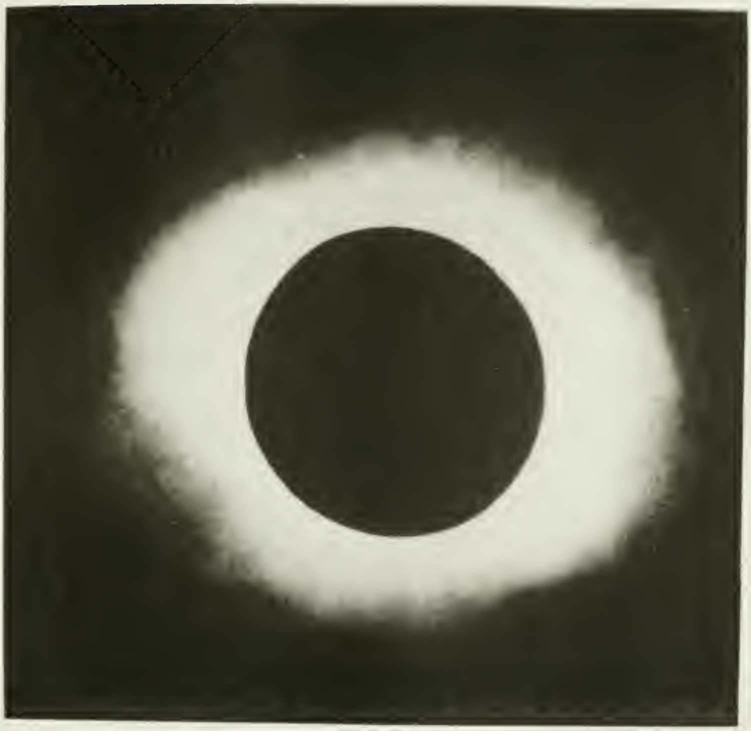
The instruments we took with us weighed about a ton, and consisted, 1st, of a telescope of 5 inches aperture and 78 inches focal length, especially corrected for photography by Alvan Clark & Sons.

This enabled me to get as well defined a photograph of the corona as could be obtained by an exposure lasting during the whole of totality, that is, 165 seconds. 2d, a large instrument which may be called a phototelespectroscope, Fig. 1. It consisted of an object-glass composed of four lenses, 6 inches in diameter and 21 inches focal length, loaned to me by Messrs. E. & H. T. Anthony of New York. The image of the sun at the focus of this instrument was less than ¼ of an inch in diameter, and of extreme brilliancy. Before the rays of the lens reached a focus they were intercepted by a Rutherford grating about 2 inches square, set at an angle of 60 degrees. This threw the rays to one side and produced three images, a central one of the sun and on either side of it a spectrum. One of these spectra was dispersed twice as much as the other, that is, would give a photograph of twice the length. This instrument was mounted equatorially, as was also the five inch telescope. They were driven by clockwork to follow the sun with accuracy. For this equatorial mounting and driving clock I am indebted to Prof. Pickering, Director of Harvard Observatory. 3d, Prof. Barker brought from the collection of the University of Pennsylvania, 2 four-inch achromatic telescopes, one with a Merz direct vision spectroscope attached to it for eye observations, the other to be used with Edison's tasimeter. Besides these there were polariscopes, a grating spectroscope, an eye slitless spectroscope with two-inch telescope, and a full set of chemicals for Anthony's Lightning Collodion Process, which in my experience is three-times quicker than any other.

Fig. 1.



Our plan of operations was as follows: 1st, the photographic and photo-spectroscopic work, as well as the eye slitless spectroscope,



HELIOGRAPH. J. CARBUTT PHILA.

FAC-SIMILE OF

PROF. HENRY DRAPER'S PHOTOGRAPH OF THE CORONA.

TAKEN JULY 29th, 1878.

were to be in charge of my wife and myself. 2d, the analysing slit spectroscope was in charge of Prof. Barker, with the especial object of ascertaining the presence of bright lines or else of dark Fraunhofer lines in the corona. 3d, the polariscopic examinations were confided to Prof. Morton, who was also to spend a few moments in looking for bright or dark lines with a hand spectroscope. 4th, Mr. Edison carried with him one of his newly invented tasimeters with the batteries, resistance coils, Thomson's galvanometer, etc., required to determine whether the heat of the corona could be measured.

This programme was successfully carried out, and entirely satisfactory results were obtained.

If the light of the corona was glowing gas giving bright lines which lay in the actinic region of the spectrum, the photograph would show ring-formed images, one ring for each bright line, while if the light of the corona arose from incandescent solid or liquid bodies, or was reflected light from the sun, I should obtain a long band answering to the actinic region of the spectrum. If the light was partly from gas and partly reflected sunlight, a result partly of rings and partly a band would be obtained. It was the general impression that it would be impossible to obtain a photograph of the diffraction spectrum of the corona, but the result proved the contrary, for on developing the photograph immediately after totality, it appeared that I had obtained a spectrum without the least trace of a ring, showing that the corona on this occasion did not consist of an incandescent gas giving a few bright lines, but that its light was due to reflection of sunlight by solid or liquid bodies surrounding the sun like a cloud of meteors.

The plain photograph of the corona (see plate), shows that the great mass of the matter lies in the plane of the ecliptic, but not equally distributed, for on this occasion it extended about a degree and a half from the sun towards the west, while it was scarcely a degree in length towards the east. The photograph also shows curious ray-like forms of coronal matter towards the poles of the sun.

There can be little doubt that during this eclipse we have observed the true nature of the corona, and that its light is almost altogether sunlight reflected from bodies of a size too small to be distinguished as individuals. According to this view, the light of the corona has, on former occasions, been infiltrated with materials thrown up from the chromosphere, notably with the 1474 matter and hydrogen. The

1474 line can be seen on any occasion favorable for observations in the chromosphere of the sun. As the chromosphere is now in a quiescent condition, this 1474 matter had not been projected into the corona as in former eclipses, and hence, probably, the pearly white color on this occasion.

The observations of both Profs. Barker and Morton confirmed this theory, that the corona shone by reflected sunlight at this time, for Prof. Barker with the analysing spectroscope observed the dark Fraunhofer lines in the corona, and the polarization was shown by Prof. Morton to be such as would answer to reflected solar light. Prof. Morton also observed the dark Fraunhofer lines in the coronal light with a hand spectroscope.

Mr. Edison used his newly invented tasimeter to ascertain whether the corona gave indications of heat. He adjusted the instrument to be very sensitive and found eventually that a much less delicate adjustment would have sufficed, for the moment the tasimeter was moved from the image of the dark moon to the image of the corona, the index beam of light went entirely off the scale of the galvanometer.

ECONOMIC VAPORIZATION OF WATER AND EXPANSION OF STEAM.

Analysis of Mr. Lavington E. Fletcher's experiments at Dalkeith, Scotland, on the engine and boilers of the paper mill belonging to the Messrs. Craig.

By Chief Engineer Isherwood, U. S. Navy.

[Continued from Vol. lxxvi, page 156.]

The steam in Regnault's well-known experiments on that substance, was generated and condensed under the *same pressure*, and its total heat above the temperature of 32° Fahrenheit, as given in his table, was measured by the quantity of heat imparted to water at the temperature of 32° Fahrenheit, by its condensation. This total heat may, for the present inquiry, be considered as composed of two quantities, namely, the quantity required to vaporize the water, and the thermal equivalent of the work done by the resulting steam in evaporating against the boiler pressure. Of these two quantities, only the former exists in the steam as heat; the latter appears as heat only when the steam is condensed, but not before—not while the steam exists as such. When steam is both evaporated and condensed under the same pressure, its condensing-water contains the total heat given by Regnault, because the heat transmuted into work during the evaporation of the steam under pressure is exactly regained by the work done by the same pressure upon the condensing steam during its condensation.

In the evaporation of steam against pressure, a measurable amount of work is done which admits of easy calculation, and its thermal equivalent being deducted from Regnault's total heat, gives the quantity of heat effecting the vaporization alone of the water; consequently, the mass of steam which enters the cylinder of a steam-engine, contains only the latter quantity of heat, the former never having been in the steam, because, though abstracted from the furnace, it was transmuted into the work of evaporation.

If steam were worked through the cylinder without expansion, or without being cut off, and exhausted into a condenser in which a perfect vacuum or no pressure existed, then the quantity of heat found in the condenser, as measured by the mass of condensing- or injection-water of a given temperature required to condense that steam into water of any given greater temperature, would be exactly equal to the heat in the steam as it entered the cylinder, in which case the total heat of steam would be less than given in Regnault's table by the thermal equivalent of the work of evaporation.

But if the steam were worked through the cylinder expansively, or cut off, the other conditions remaining as just described, then the quantity of heat found in the condenser would be less than the quantity in the steam when it entered the cylinder, by exactly the thermal equivalent of the work done by the expanded steam, or after the closing of the cut-off valve, which thermal equivalent is abstracted from the heat in the expanded steam.

The effect of this abstraction of heat from the mass of steam in the cylinder, after its isolation from the boiler by the closing of the cut-off valve, is to condense to water, of the temperature of the remaining steam, the necessary quantity to furnish the heat transmuted into the work done by the expanded steam. The weight of this water of condensation, due to such work, can be exactly calculated: the water itself remains intimately mingled, as fine spray, with the expanded steam, and is swept with the latter into the condenser, where it is cooled by the injection-water, from the temperature of the steam in the cylinder at the end of the stroke of the piston down to the temperature of the condenser.

If steam were a perfect gas, obeying the laws of such an ideal substance, a given mass always occupying bulks in the inverse ratio of its pressure, and never losing the gaseous form by the abstraction of heat, then the work done upon the condensing-steam in the condenser by the pressure there, would exactly equal the work of evaporation done in the boiler, less the work done by the expanded steam in the cylinder; in which case, the calculation of the quantity of heat to be found in the condenser would only require multiplying the number of pounds of steam entering the cylinder, by Regnault's total heat above the temperature of the condenser, and subtracting the thermal equivalent of the work done by the expanded steam. But as steam, instead of being a perfect gas, is a very sensitive vapor, such a process would give only an approximate result.

The quantities on lines 56 to 62, both inclusive, have been calculated according to the above considerations.

Line 56 contains the number of Fahrenheit units of heat above the temperature of the hot-well, in the steam which entered the cylinder during the experiments. These quantities are the products of those on line 10, by Regnault's total heat of steam above the hot-well temperature, less the thermal equivalent of the work of evaporating the steam.

The thermal equivalent, H, in Fahrenheit units, of the work of evaporating one pound of water under the pressure, in pounds per square inch, p, is obtained from the formula, $H = \frac{V \times p \times 144}{789\frac{1}{4}}$: in which V is the number of cubic feet occupied by one pound of steam of the pressure p, 144 are the number of square inches in a square foot, and 789¼ are the dynamical equivalent in foot pounds of one Fahrenheit unit of heat.

Line 57 contains the number of Fahrenheit units of heat added to the steam in the condenser during its condensation into water of the hot-well temperature, by the work done upon it by the pressure in the condenser.

The weight of steam, as such, entering the condenser is less than the weight of steam (line 10) entering the cylinder by the weight condensed in the cylinder to furnish the heat transmuted into the number of total horses-power (line 37) developed by the expanded steam. The weight, W, of steam thus condensed in the cylinder, during the experiments, is obtained, in pounds, from the formula,

$$W = \frac{41{\cdot}811847 \times HP \times m}{L},$$

in which $\left(\frac{33000}{789\frac{1}{4}} = \right)$ 41·811847 are the number of Fahrenheit units of heat equivalent to the work of one horse-power, HP is the total number of horses-power (line 37) developed by the expanded steam; m is the time, in minutes, during which the experiment or development of power lasted; and L is the latent heat of steam of the pressure at the end of the stroke of the piston (line 29). Consequently, the pounds weight of steam entering the condenser, during the experiments, are the quantities on line 10, minus W.

The quantities on line 57 are calculated from the following formula:

$$H = W' \times \frac{\left(V' - \frac{1}{v-1}\right) \times p' \times 144}{789\frac{1}{4}},$$

in which H is the units of heat sought; W' is the pounds weight of steam entering the condenser during the experiments; V' is the number of cubic feet occupied by one pound of steam of the pressure p'; v is the relative volume of steam of this pressure, and the water of the hot-well temperature from which it was generated; p' is the pressure in the condenser in pounds per square inch; 144 are the number of square inches in a square foot, and $789\frac{1}{4}$ are the dynamical equivalent of one Fahrenheit unit of heat.

The quantities on line 58 are the number of Fahrenheit units of heat (H) absorbed by the condensing- or injection-water, in reducing the number of pounds of water of condensation due to the production of the power on line 37, from the temperature of the steam at the end of the stroke of the piston (line 29) to the temperature of the hot-well (line 23).

If h be the Fahrenheit units of heat in the water of condensation due to the production of the power by the expanded steam, when this water is at the temperature of the steam at the end of the stroke of the piston, and h' be the Fahrenheit units of heat in the same water when at the temperature of the hot-well, W being the pounds weight of this water, then $H = W \times (h - h')$.

The quantities on line 59 are the number of Fahrenheit units of heat (H) abstracted from the expanded steam in the cylinder, after the closing of the cut-off valve, by transmutation into the total horses-power (line 37) developed during the experiments by the expanded steam after the closing of the cut-off valve. These quantities are calculated from the following formula:

$$H = 41{\cdot}811847 \times HP \times m.$$

The quantities on line 60 are the remainders of the sum of the quantities on lines 56, 57 and 58, after the subtraction of the quantities on line 59, and show the number of Fahrenheit units of heat which should have been found in the hot-well in the injection- or condensing-water.

Now the quantities on line 60 are evidently too small, owing to causes foreign to the above stated principles of calculation and operating a loss of heat by the water in the hot-well. These causes might be avoided, or their effect ascertained and allowed for, but this was not done in the present experiments. The temperature (line 23) of the water in the hot-well is too low, owing to the loss of heat by external radiation from the exhaust-pipe, air-pump, condenser and hot-well surfaces in contact with the atmosphere; in a word, from all the external surfaces of the pipes and vessels between the cylinder and the point at which the temperature of the hot-well water is taken. The temperature of this water was likewise further reduced, by evaporation from its exposed surface into the air. In a very accurate experiment these surfaces should be protected by a non-conducting covering, and the temperature of the water ascertained in a closed hot-well.

During these experiments there was, of course, a constant evaporation going on into the air from the surface of the water, in both the feed-water tank and the hot-well water tanks, which might have been ascertained and allowed for, but the effect of which was to make the weight of both the feed-water and the hot-well water appear too great; thus, in measure, establishing a compensation when the quantity of heat in the condensing-water, as ascertained by calculation from the weight of feed-water consumed, is compared with the quantity of heat in the condensing-water, as directly measured. It is, of course, assumed that there is no leakage of water or steam between the feed-water tank and the hot-well water tanks. Any water foamed over, or primed with the steam from the boiler into the cylinder, need not be considered in this investigation, because it will be vaporized in the cylinder and enter the condenser as steam, the heat of its vaporization being obtained from the boiler by means of the metallic surfaces of the cylinder. The only effects of such priming are the lessening of the power developed by the engine, and the increasing, apparently, of the economic vaporization by the boiler.

Line 61 gives the number of Fahrenheit units of heat actually found in the condensing-water. These quantities are calculated by multiplying the difference of the quantities on lines 12 and 10, by the difference in the units of heat in water of the temperatures on lines 22 and 23.

Line 62 shows the difference, due to all causes, between the number of Fahrenheit units of heat that should have been found in the condensing-water, according to calculation (line 60), and which were there, by direct observation (line 61), expressed in per centum of the latter.

In all cases, the difference of the specific heat of water of different temperatures has been allowed for.

REMARKS.

Of the Effect of the Measure of Expansion with which the Steam is used, on the Economic Development of the Power.—Omitting, for the present, the consideration of the economic results of experiment C, and comparing those of experiments D and E, in which there was no steam in the jackets of the cylinder, but in which the steam was expanded, respectively, 2·3876 and 2·5842 times, it will be perceived that the greater measure of expansion was accompanied by a less economic result, the total horse-power in experiment D being obtained for an expenditure of 26474·0151 Fahrenheit units of heat per hour, while in experiment E it was obtained for 28395·3372 units. This very great difference of 6·77 per centum of the greater quantity, for so very small a difference in the measure of expansion, is impossible, and only proves errors of observation. It will be entirely safe to assume there was no difference in the economic results of these two experiments, and that for the average measure of expansion of $\left(\frac{2{\cdot}3876 + 2{\cdot}5842}{2} =\right)$ 2·4859 times, the total horse-power cost an expenditure of $\left(\frac{26474{\cdot}0151 + 28395{\cdot}3372}{2} =\right)$ 27434·6762 Fahrenheit units of heat per hour.

Comparing the economic results of experiments A and B, in which the steam-jackets of the cylinder were filled with steam of the boiler pressure, and in which the steam was expanded, respectively, 5·710 and 4·448 times, it will be observed that the greater measure of expansion was again accompanied by a less economic result, the total horse-power in experiment A being obtained for an expenditure of 24722·3538 Fahrenheit units of heat per hour; while, in experiment B, it was obtained for 23197·9061 units. This difference of 6·17 per centum of the greater quantity, against the greater measure of expansion, shows errors of observation. It will be quite safe to assume there was no difference in the economic results of these two experiments, and that, for the average measure of expansion of $\left(\frac{5{\cdot}710 + 4{\cdot}448}{2} =\right)$ 5·079 times, the total horse-power cost an expenditure of $\left(\frac{24722{\cdot}3538 + 23197{\cdot}9061}{2} =\right)$ 23960·1300 Fahrenheit units of heat per hour.

Comparing, now, the average economic results of experiments A and B, in which steam of an average initial pressure of $\left(\frac{58{\cdot}97 + 58{\cdot}02}{2} =\right)$ 58·50 pounds per square inch above zero was used, with an average expansion of 5·079 times, in a cylinder whose jackets were filled with steam of the average pressure of 72·19 pounds per square inch above zero, with the average economic results of experiments C and D, in which steam of an average initial pressure of $\left(\frac{41{\cdot}88 + 39{\cdot}78}{2} =\right)$ 40·83 pounds per square inch above zero was used, with an average expansion of 2·4859 times, in a cylinder whose jackets were not filled with steam; experiments A and B exceed experiments D and E, in the economic production of the power, $\left(\frac{27434{\cdot}6762 - 23960{\cdot}1300 \times 100}{27434{\cdot}6762} =\right)$ 12·665 per centum; 12⅔ per centum is all the economic gain obtained from using steam of (58·50 — 40·83 =) 17·67 pounds greater initial pressure per square inch above zero, with double the measure of expansion (2·4859 and 5·079 times), in a steam-jacketed cylinder, the temperature in the jackets being 60·84° Fahrenheit greater than that of the mean steam pressure (line 33) in the cylinder. How much of this small gain is due to the greater initial pressure? how much to the greater measure of expansion? and how much to the steam-jacketing? Unfortunately, the data of the experiments do not permit an answer to these interesting questions.

In experiment C, steam of the initial pressure of 41·48 pounds per square inch above zero, was used with an expansion of 1·882 times in a cylinder whose steam-jackets were filled with steam of 47·19 pounds pressure per square inch above zero, under which conditions the total horse-power (line 36) was obtained for an expenditure of 27011·1996 Fahrenheit units of heat per hour, or about 1·55 per centum less than the average (27434·6762 units) of experiments D and E, made without steam in the cylinder-jackets, but with about the same initial pressure expanded 2·4859 times. Now, is this near equality to be attributed to a compensation established in experiment C, between a supposed loss by the less measure of expansion employed, and a supposed gain due to the presence of steam in the cylinder-jackets? Such a view may properly be taken, and the data are wanting in these experiments to sustain or overthrow it.

Experiment C is the most anomalous of the experiments, and its results cannot be reconciled with those of the others. It was greatly shorter than they, and the indicator diagrams taken were proportionally fewer. The writer is of the opinion that the horses-power developed in it are considerably too small. That there is a large error in it somewhere, is apparent from the fact that the condensation in the cylinder, other than due to the development of the power (line 51), is about equal to the mean condensation in experiments D and E, where steam of about the same initial pressure was expanded one-third more, and in a cylinder without steam in its jackets. Such a result is opposed to every other experiment of which the writer has knowledge. Further, the discrepancy (line 62) between the heat that should have been found in the condensing water, and the heat actually found in it, is too great for accuracy. The writer is of opinion that experiment C should be rejected. If it be accepted, it shows, on the supposition of steam in the cylinder-jackets being non-effective, that between the measures of expansion, 1·882 and 2·5842 times, the economic development of the power was not affected by the measure of expansion with which the steam was used; or, if the presence of steam in the jackets be supposed effective, then it shows that such efficiency about equaled the economic gain due to increasing the measure of expansion from 1·882 to 2·5842 times.

The supposition of the non-effectiveness of steam in the jackets, combined with the equality of the economic production of the power, with measures of expansion ranging from 1·882 to 2·5842 times, does not accord with the fact that when the latter measure of expansion was increased to 4·448 times (experiment B), and to 5·710 times (experiment A), there resulted an economic gain of about one-eighth. Why should there have been so great an increase in the economy of the steam when used with these latter measures of expansion, than when expanded 2·5842 times, while there was no gain for an increase in the measure of expansion from 1·882 to 2·5842 times, and when there was a loss instead of a gain in going from an expansion of 4·448 to 5·710 times? Nature does not proceed *per saltum.*

If the presence of steam in the steam-jackets is admitted to be as effective in these as it has been found to be in all other experiments made with steam-jacketing, then the one-eighth gain in economy found in experiments A and B, over the results in experiments D and E, is due wholly to the presence of steam in the jackets during the former, and not at all to the increased measures of expansion with which the steam was used in them.

But, taking the experiments as they stand, the fact is apparent that, with the same initial pressure in the cylinder, the engine making the same number of double strokes of piston per minute, and developing the same net horses-power, the area of the piston being proportionately larger with the greater measures of expansion, the net or commercially valuable horse-power would be obtained for as small an expenditure of heat per hour when the steam was used with an expansion of 1·882 times, as when it was used with any greater measure of expansion up to 5·710 times.

All the above comparisons have been made for the cost of the total horse-power in Fahrenheit units of heat expended per hour. This is equivalent to a comparison of the cost of the net horse-power, on the supposition that the same cylinder is employed with the same speed of piston, and the same net pressure upon the piston per square inch; which requires a proportionately higher and higher initial pressure as the measure of expansion is greater and greater.

Relative Economic Efficiencies of the two kinds of Boilers and Coals.—A comparison of the vaporization results in experiments A and E (line 54), shows that with the Sinclair boiler, notwithstanding its large proportion of 35·95 square feet of heating-surface per square foot of grate-surface, an increase in the rate of combustion of Scotch bituminous coal, from 13·2321 to 16·6076 pounds per hour per square foot of grate-surface, decreased its economic vaporization $\left(\frac{8{\cdot}2337 - 7{\cdot}3946 \times 100}{8{\cdot}2337} = \right)$ 10·19 per centum.

The Scotch bituminous coal consumed in the Sinclair boiler (experiment A), gave an inferior economic vaporization (line 54) to the Welsh semi-bituminous coal consumed in the same boiler (experiment B) of $\left(\frac{10{\cdot}0569 - 8{\cdot}2337 \times 100}{10{\cdot}0569} = \right)$ 18·33 per centum, both coals vaporizing about the same weight of feed-water per hour from the same temperature.

The common Lancashire boiler having the small proportion of 19·08 square feet of heating-surface per square foot of grate-surface, gave, when burning the Scotch bituminous coal at the rate of (mean of experiments C and D, $\frac{22{\cdot}7808 + 23{\cdot}1694}{2} = \Big)$ 22·9751 pounds per hour per square foot of grate-surface, a vaporization of $\left(\frac{6{\cdot}0174 + 5{\cdot}9990}{2} = \right)$ 6·0082 pounds of water from the temperature of 100° Fahrenheit per pound of coal. The weight of water vaporized per hour from this temperature was, for the average of the two experiments, 5052 pounds.

The Sinclair boiler, when vaporizing (experiment E) 4851 pounds of water per hour from the temperature of 100° Fahrenheit, or nearly the same, and burning the same Scotch coal at the rate of 16·6076 pounds per hour per square foot of grate-surface, gave a vaporization of 7·3946 pounds of water per pound of coal; consequently, when supplying equal weights of steam in equal time with the same coal, the Lancashire boiler was $\left(\frac{7{\cdot}3946 - 6{\cdot}0082 \times 100}{7{\cdot}3946} = \right)$

18·75 per centum less economical than the Sinclair boiler, exhibiting in a striking degree the economic advantage of a high proportion of heating- to grate-surface, and a low rate of combustion; in other words, of employing an apparatus large in proportion to the work to be done. It also exhibits how great may be the errors in comparing the cost of the indicated horse-power in pounds of coal consumed per hour, for engines supplied with steam from boilers of different types and proportions, burning coals of widely varying vaporizing power with widely varying rates of combustion. Such comparisons can be only for the systems as a whole, and give no information as to the economic efficiency of any part. Those can only be comparative experiments which are made under comparable conditions, and the whole of the data—every fact influencing the final result—must be ascertained and stated separately.

Untrustworthiness of Measuring the Economic Development of the Power by the Heat acquired by the Condensing-Water.—Many persons have advocated using the number of units of heat acquired by the condensing-water in an hour per indicated horse-power, as the measure of the economy of the engine; but the results of these experiments show this method to be incorrect in principle, even when the thermal units due to the development of the power are added. Such comparisons will not be accurate, either absolutely or relatively. In these five experiments, all by the same observers with the same instruments, the discrepancies range from 6·6372 to 22·6336 per cent. (line 62), and prove how little trustworthy are results from this process.

Economy of the Feed-Water Heater.—When the feed-water heater was in use, during experiments A and B with the Sinclair boiler, the temperature of the feed-water was raised about 100° Fahrenheit, or from 100° to 200°, equivalent to an economic gain in fuel of about 9 per centum. The surface of the heater exposed to the gases of combustion in the flue behind the boilers, is not given, but the temperature of those gases exceeded 800° Fahrenheit, as they came from the Lancashire boilers as well as from the Sinclair boiler. Had the heater been exposed to the temperature of the waste gases from the latter boiler alone (400° to 450° Fahrenheit), nothing like this 9 per centum of economy would have been realized.

Condensation of Steam in the Steam-Jackets.—The mean results from experiments A, B and C, show, that of the total weight of steam evaporated in the boiler, $3\frac{1}{3}$ per centum was condensed in the steam-jackets of the cylinder. This per centum is greatly less than the truth—probably one-eighth less—owing to the causes hereinbefore stated. Now, as the jackets were supplied with boiler-steam by a small independent pipe, and had no communication with the main steam-pipe, no water could have been primed over into them, and the whole of what was found in them must have been due to the absorption of heat by the steam within the cylinder, for the insignificant quantity of heat lost by external radiation from the small and well protected surfaces of the jackets, need scarcely be allowed for. This absorption of heat from the jackets by the working steam within the cylinder, must have effected some economy in the production of the power.

MEMOIRS ON THE LIQUEFACTION OF OXYGEN, THE LIQUEFACTION AND SOLIDIFICATION OF HYDROGEN, AND ON THE THEORIES OF THE CHANGES IN CONDITION OF BODIES.

By R. Pictet.

IV.—Calculation of the Density of Liquid Oxygen.

MAXIMUM TENSIONS.

[Continued from Vol. lxxvi, page 165.]

Measurement of the Temperatures.—In a preceding chapter we gave a general formula, which we had derived, directly by analysis, from the mechanical theory of heat. This formula makes the maximum pressures dependent on the corresponding temperatures. It comprises besides, in its factors, the latent heat of volatilization at a temperature taken as a base, as well as the difference $c - k$, of the specific heat of the liquid, less that of the vapor. This formula is

$$l\left(\frac{P'}{P}\right) = \frac{[\lambda' + (c - k)(t' - t)]\, 431 \times 1{\cdot}293\, \delta \times 274\, (t' - t)}{10333\, [(274 + t')^2 - (274 + t')(t' - t)]}.$$

In this formula the following quantities are supposed to be known,

P' at t', λ', $(c - k)$ and δ.

As the analytical demonstration of this formula has not as yet been published, we do not think ourselves authorized to use it without having verified it by at least one example, as applied to water, all of whose properties have been determined with so much care by M. Regnault.

We by no means wish to substitute an example for a demonstration, but a numerical verification of this nature will have the double advantage of showing in detail the method of using this formula, and the perfect agreement of the numerical results.

We will thoroughly discuss this subject in a forthcoming work, which is not as yet completed.

For the numerical verification of the formula, let us take the following data as given in the tables of M. Regnault: $t'^{\circ} = 200^{\circ}$; $t = 82^{\circ}$; P' corresponding to $t = 11688{\cdot}96$ millimetres of mercury; δ, the density of the vapor of water, is given by the curve of co-volumes $= 0{\cdot}62665$; $\lambda' = 464{\cdot}3$ calories; $c - k$, according to M. Regnault, between 200° and $82^{\circ} = 0{\cdot}544$.

We have thus arbitrarily chosen a sufficiently great difference as

$$t' - t = 118 \text{ degrees.}$$

We have to solve the numerical equation:

$$l\left(\frac{11688{\cdot}96}{x}\right) = \frac{[464{\cdot}3 + 0{\cdot}544 \times 118]\ 431 \times 1{\cdot}293 \times 0{\cdot}62665 \times 274 \times 118}{10333\ [(274 + 200)^2 - (274 + 200)\ 118]}.$$

Performing this calculation with the aid of logarithms, we arrive at the following result:

$$\begin{array}{lll}
\text{l. Numerator} & = 9{\cdot}7747759 & \\
\text{l. Denominator} & = 9{\cdot}2414547 & \\
\hline
\text{Difference,} & \ 0{\cdot}5333212 & \\
\text{l. Modulus,} & \ 0{\cdot}3622157 & \\
\hline
 & \ 0{\cdot}1711055 & \text{is log of } 1{\cdot}482871 \\
\text{Log } P' = & \ 4{\cdot}0677740 & \\
 & \ 1{\cdot}482871 & \\
\hline
 & \ 2{\cdot}5849030 & \text{is log of } 384{\cdot}51 \text{ mm.} \\
x = & \ 384{\cdot}51 &
\end{array}$$

If we now take the tension of the vapor of water, corresponding to 82°, from M. Regnault's tables, we will find it equal to 384·435 mm. This example suffices to show that our formula represents, with great exactitude, the function which makes the temperature dependent on the pressure.

We intend employing this formula, as applied to sulphurous acid, as a substitute for the readings of the alcoholic thermometer. In this manner, we will obtain dynamometric thermometers of great sensitiveness, which may be substituted for the entirely unreliable readings of all kinds of thermometers when exceeding —20° or —25°.

The complete solution of the numerical calculations rendered necessary by this transformation, is not as yet finished, as we wish to obtain several experimental verifications regarding imperfectly understood properties of the volatile liquids employed. To a certain extent we are therefore still obliged to fall back on the alcoholic thermometer. M. Salleron, of Paris, has made ten for me, graduated to — 100°, which I have used.

I have found that carbonic acid is transformed into a vapor under a pressure of 760 at a temperature of — 80°.

As our pumps can produce an almost perfect vacuum over this solid carbonic acid, the thermometers will no longer suffice, even for an approximate knowledge of the temperature produced; the thermodynamic formula must be employed.

In order to determine the value of λ' for carbonic acid at — 80°, I have employed two formulæ, previously demonstrated in a former publication already cited.[1] The first is

$$\lambda^{-80} = \frac{10333\,(274 - 80)^2}{1{\cdot}293\delta \times 431 \times 274} \times \left\{ \begin{array}{l} \text{A factor derived from the pres-} \\ \text{sures with regard to temperatures.} \end{array} \right.$$

The second gives the value of this derived quantity, which we will call D; it is

$$D = \frac{0{\cdot}041 \times 274}{274 - 80}.$$

Carrying out the numerical calculation and substituting for D, its value, we find for λ^{-80}:

$$\lambda^{-80} = 96{\cdot}766 \text{ calories.}$$

We have taken for the density at 0°, $\delta = 1{\cdot}5241$ (Regnault), λ' once known, we made the calculations for the curve represented in Plate II, by means of our general formula giving to t a series of values from 10 to 10 degrees. The abscissæ of this curve represent the temperatures, and the ordinates, the corresponding pressures.

Therefore, if the pressures indicated by the mercurial manometer be known, when a vacuum is established over the carbonic acid, we can determine the temperature of this body with the aid of this curve. There are many elements in this determination which are but imperfectly known, many figures to be corroborated by direct experiments, we therefore only advance this measurement of the temperatures "as a first approximation."

---

[1] *Archives des Sciences phys. et. nat.* Janvier, 1876.

The following is the calculation for the temperature — 120° :

$$\lambda' = 96{\cdot}766 \text{ calories.}$$

$(c - k) = 0{\cdot}1947$ deduced from analogy of isomorphous bodies.

lg 104·554 = . . 2·0193407
lg 1·5241 = . . 0·1830135
lg 1·293 = . . 0·1115985
lg 431. = . . . 2·6344773
lg 274· = . . . 2·4377506
lg 40· = . . . 1·6020600

lg numerator = . . 8·9882406
lg 10333 = . . 4·0142264
lg $(194^2 - 194 \times 40)$ = . 4·4753225
lg $\frac{1}{m}$ = . . . 0·3622164

lg denominator = . . 8·8517646
lg quotient = . . 0·1364760 log of 1·36923
lg 760 = . . . 2·8808136
1·36923

1·5115836 log of 32 mm. 488

The pressure corresponding to — 120° is 32·488 millimetres of mercury.

By means of identically the same calculations, the curve *A* of the tensions of carbonic acid has been found.

We have made similar determinations for protoxide of nitrogen. The results are given by curve *B*, calculated from 10° to 10°.

As a starting point, we took a pressure of — 92° with the barometric pressure of Geneva, which is 730 millimetres. That is, the temperature of ebullition of this liquid, determined by observation.

The two curves, *A* and *B*, show that the protoxide of nitrogen has greater tension than carbonic acid. We can therefore attain lower temperatures with the protoxide of nitrogen than with carbonic acid.

Our pumps *O* and *O′*, which exhausted the vaporized carbonic acid in tube *D* (Fig. 1), produced a vacuum of 9 millimetres. The pressures oscillated between 8 and 12 millimetres, according to the speed of the pumps. We may therefore infer, that "the temperature corresponding to the first three experiments, made with carbonic acid, was about — 130°; and — 140° for the last two, made with protoxide of nitrogen."

From these results we find that the maximum tension of liquid oxygen is at

— 130° pressure, . .	273 atmospheres.
— 140° " . .	252 "

A difference of about 10° would produce an increase of pressure of 21 atmospheres.

Such are for the present the numerical conclusions furnished by these first experiments.

We stated previously, that the protoxide of nitrogen gave us different pressures from those given in works on physics. We noticed it in this manner:

While making the preliminary investigations which led us to the mechanical apparatus employed, in order to determine which of the two liquids should be chosen to obtain the greatest cold, I compared the two following tables, which give the maximum tensions of carbonic acid and of protoxide of nitrogen.

Temperature.	Carbonic Acid.	Protoxide of Nitrogen.	Difference.
— 87·2		1 atmos.	
— 84·4		1·10	
— 81·7		1·22	
— 80·	1 atmos.		
— 78·9		1·37	
— 77·2	1·36		
— 76·1		1·55	
— 73·3		1·77	
— 70·5	2·28	2·03	+ 0·25
— 67·8		2·34	
— 63·9	3·6		
— 62·2		3·11	
— 59·4	4·6	3·58	+ 1·02
— 51·	7·	5·36	+ 1·64
— 48·8	7·7		
— 48·3		6·09	
— 37·2		9·74	
— 36·6	12·5	9·91	+ 2·59

An examination of this table shows that the pressures are nearly the same for both liquids; however, between the temperatures of

— 75° and — 36·6°, "the tensions of protoxide of nitrogen are always less than the corresponding ones of carbonic acid." This decided me, at first, to employ carbonic acid, which, according to this table, should produce the greatest cold in a vacuum. For the formula which allies the tensions to the temperatures, shows that if a liquid at any temperature possess a higher tension than another liquid at the same temperature, this difference will very probably exist for all temperatures with the same sign. As temperatures of — 35° to — 50° are much more reliable than those indicated by alcohol at — 75° to — 80°, I felt constrained to place more confidence in the pressures indicated at these higher temperatures. But, on substituting pure protoxide of nitrogen, made from crystallized nitrate of ammonia, for carbonic acid, during the last two experiments, I found for this body, pressures notably higher than those of carbonic acid. There is, consequently, a manifest error in the tables prepared by Faraday and other experimentalists. These differences are so marked, that I thought, for a while, that air had found its way in and increased the pressure of the condensing gas.

To be assured of the contrary, I condensed all the contents of the gasometer, in the tube *S*, then I distilled it. The vapors slowly reentered the gasometer. After having thoroughly emptied it, so as to remove every trace of a foreign gas, the pressures indicated by the manometer corresponded exactly to the maximum tensions of liquid protoxide of nitrogen. The pumps not working, the temperature indicated by the alcoholic thermometer afforded a means of following, degree by degree, the continued elevation of temperature. This method presents the decided advantage of allowing a long-continued observation. The temperature indicated by the thermometer is certainly equal to or but slightly higher than that of the protoxide of nitrogen; consequently, the indications of the manometer are, in all cases, *minima*.

We have prepared the following table for carbonic acid and protoxide of nitrogen:

Temp.	Carb. Acid.	Prot. Nitrog.	Differences.
— 92°		1 atmos.	
— 90°		1·10	
— 88°		1·15	
— 86°		1·35	
— 84°		1·40	
— 82°		1·72	
— 80°	1 atmos.	1·90	— 0·90

Temp.	Carb. Acid.	Prot. Nitrog.	Differences.
— 78°	1·15 atmos.	2·12 atmos.	— 0·97
— 76°	1·33	2·36	— 1·03
— 74°	1·55	2·60	— 1·05
— 72°	1·78	2·85	— 1·07
— 70°	2·08	3·15	— 1·07
— 68°	2·41	3·50	— 1·09
— 66°	2·71	3·80	— 1·09
— 64°	3·10	4·20	— 1·10
— 62°	3·45	4·60	— 1·15
— 60°	3·90	5·05	— 1·15
— 58°	4 40	5·50	— 1·10
— 56°	4·90	6·10	— 1·20
— 54°	5 46	6·32	— 0·86
— 52°	6 10	7·05	— 0·85
— 50°	6·80	7·63	— 0·83
— 48°	7·40	8·30	— 0 90
— 46°	8·05	9·00	— 0·95
— 44°	8·72	9·60	— 0·88
— 42°	9·45	10·30	— 0 85
— 40°	10·25	11·02	— 0·77
— 38°	11 00	11·70	— 0·70
— 36°	11·90	12·50	— 0·60
— 34°	12·70	13·19	— 0·49

This table, prepared immediately after repeated experiments, shows us that protoxide of nitrogen always has a higher tension than carbonic acid, which agrees with the theoretical inferences we have drawn. We give this table *in extenso* as the differences between the pressures given in works on physics are too great, and correspond to temperatures too far apart. We also desired to compare carbonic acid and protoxide of nitrogen, directly and under identically the same conditions, with each other.

The general table of our experiments, as given at the end of last chapter, furnishes us with still another absolute proof of the liquid state of the oxygen.

In three experiments (Nos. 2, 4 and 5), the third jet was of but short duration, and I closed the regulating cock quite suddenly. This allowed a small quantity of liquid oxygen to adhere to the sides of the tube.

The rapid evaporation lowered the temperature of the sides several degrees, while the vapors formed escaped through the cock. At the moment of closing, the pressure was 245 atmospheres in the second experiment. Several instants later, it rose to 253 atmospheres. This increase of pressure at a time when the production of gas has long ceased, can only be explained by admitting that a small quantity of oxygen passes back from the liquid to the gaseous state.

The conductivity of the copper sides of the tube is sufficient to very rapidly restore an equilibrium of temperature. In the two other experiments, the pressure rose from 213 to 215 atmospheres, and from 205 to 212 atmospheres.

SOLIDIFICATION OF THE OXYGEN.

In the third and fourth experiments, we used the electric light, condensed by a reflector, to examine the appearance of the issuing jet. This intense light enabled us to clearly distinguish two parts in the fluid stream. A central portion partially transparent of 2 to 3 mm. diameter, and a surrounding envelope of from 10 to 12 mm., of a brilliant white. These two concentric envelopes resembled two cylinders, one inside the other. The exterior one seemed to consist of a dust, like chalk or snow. Their length was about 10 to 12 centimetres. We endeavored to determine the nature of this white substance, to know if it might be solidified oxygen.

In this research we made use of polarization. By examining light reflected at a right angle with regard to the incidental rays, with a Nicol's prism, it is easy to determine whether or no it is polarized. The reflector placed 2 metres from the orifice of the jet, threw horizontal rays on the oxygen. M. H. Dufour, professor of physics at the Academy of Lausanne, had the kindness to examine the light reflected by the jet; placing himself so that the rays observed in the analyzer were emitted perpendicularly to the axis of the parabolic reflector. During the jet the Nicol prism was turned 90°; during its rotation, M. Dufour observed distinctly a notable difference in the intensity of this light, which proves that it was partially polarized, at least. This experiment should be repeated several times, and would seem to indicate that the oxygen which issues from the tube, evaporates with such energy that the liquid particles are transformed into small solid crystals, a real dust of frozen oxygen. The heat of the surrounding air almost instantly retransforms these crystals into gas.

This is the general character of the different results furnished us by these experiments. They are still quite incomplete and demand verification, and especially corroboration by other allied researches. We must endeavor to render this liquid oxygen visible, by condensing it in a transparent receptacle. The problem is a very complicated one, bristling with mechanical difficulties.

We must prevent the natural deposit of hoar frost on the cold surfaces, which mars their transparency. We must have tight joints with fragile bodies, etc., etc. Finally, we will do what we can to circumvent all these obstacles.

(To be continued.)

ON THE DEVELOPMENT OF THE CHEMICAL ARTS, DURING THE LAST TEN YEARS.[1]

By Dr. A. W. Hofmann.

From the *Chemical News.*

[Continued from Vol. lxxvi, page 173.]

Where circumstances admit, the animal charcoal, after being used for clarification, is incinerated, and the ash is further utilized. Or the recent bones are treated with hydrochloric acid to extract the phosphates, and the residual cartilage is used in the glue manufacture. Upon this H. Fleck founded a very rational process[ii] which A. W. Hofmann has already discussed in Report, but which does not yet appear to have been universally introduced, though the objections raised on account of the want of suitable vessels for the evaporation of the lyes might not be insuperable.

Similar has been the fate of Metrand's ingenious proposal to act with hydrochloric acid gas upon an intimate mixture of equal parts of bone-ash and wood-charcoal, thus obtaining phosphorus, a method also mentioned by Hofmann. Instead of bone-ash a natural phosphate might serve, or one prepared by precipitating the hydrochloric solution of bones with lime. The chloride of calcium thus obtained could be used without difficulty for the reproduction of hydrochloric acid, so that the final result would be sulphate of lime containing a small proportion of phosphates, which might be very well utilized as manure.

---

[1] "Berichte über die Entwickelung der Chemischen Industrie während des letzten Jahrzehends."

[ii] "Verbessertes Verfahren der Phosphor Fabrikation." Hugo Fleck. Leipzig, 1855. See *Wagner Jahresber.*, 1855, 66.

Recently the process suggested years ago by Wœhler to decompose phosphate of lime with silica and carbon has been carried out on the large scale at Coignet's works in Lyon, having been rediscovered by Aubertin and Robiquet.[i] We must not forget that Brand first obtained phosphorus by distilling urine previously to dryness with sand.

Brisson has modified Wœhler's process by adding soda to the abovementioned mixture, and heating in shaft-furnace. The operation must be managed in such a manner that the liberated phosphorus may not come in contact with the air, which is not very easily arranged.[ii]

In England, sombrerite, which is found abundantly in the Antilles, and especially in the island of Sombrero, is said to be used for obtaining phosphorus. In consists of 49·6 phosphoric acid, 42·7 lime, 6·5 alumina, and 1·1 moisture.[iii]

Another West Indian mineral known as Redonda phosphate is used in England, consisting chiefly of alumina and phosphoric acid, along with some iron. Spence opens up the mineral, after ignition and pulverization, by boiling with sulphuric acid. By the introduction of ammonia from gas-liquors ammonia-alum is formed and readily removed by crystallization. The mother-liquor contains principally phosphate of ammonia, which may be used in the manufacture of manure.

Gerland extracts bones, previously deprived of fat, with sulphurous acid, and heats the solution when the phosphates are deposited, whilst the acid escapes and may be re-used.[iv] This process appears to be in use in France, where patents for its execution have been taken out by several manufacturers.[v]

As far as the reporter is aware the total supply of phosphorus is furnished at present by two establishments only; the firm of Albright and Wilson, of Oldbury, near Birmingham, and by Coignet and Son, of Lyon. O. Pauli, who formerly managed the works of Schattenmann, at Buxweiler, near Strasburg, produced there, and subsequently in his own manufactory at Karlsruhe, phosphorus of excellent quality, and employed Seubert's ingenious process for drawing the product into rods. According to recent intelligence the manufacture there has been abandoned, and in general no phosphorus is produced in Germany, a fact evidently depending on the price of the raw material.

---

[i] *Moniteur Scientif.*, 1869, 173.

[ii] *Wagner Jahresber.*, 1869, 223.

[iii] *Wagner Jahresber.*, 1862, 247. An attempt has also been made to use phosphate of iron instead of phosphate of lime in the preparation of phosphorus. Details are not known and success is improbable.

[iv] *Bul Soc. Chim.*, ii, 1864.

[v] *Zeitscher. f. Ch.*, 1870, *Journ. f. Prakt. Ch.*, iv, 67, 1870.

In Austria, also, phosphorus is at present no longer produced. Ploy formerly fitted up a manufactory at Obernberg, in Upper Austria, and subsequently, in 1849, at Manning, in the same province; but the production, which amounted to 250 cwts. annually, ceased in 1865. Another establishment was opened in 1853 by Baron Riese-Stallburg, at Wranowitz, in the circle of Pilsen, in Bohemia, where about 180 cwts. of phosphorus were yearly produced. This manufactory also was discontinued in 1865.

The firm of J. D. Stark, who, in 1847, introduced the manufacture of phosphorus on a large scale at their works at Kasnau, in Bohemia, abandoned it in 1868. In a pamphlet issued by opportunity of the Exhibition, under the title "The Firm J. D. Stark, their Mines, and Manufactories of Mineral," compiled by A. Prochaska, manager of the works at Kasnau, the reason alleged was the high price of bones, due to the great development of the sugar manufacture in Austria, and especially in Bohemia, and to their consumption in agriculture both as bone-dust and in artificial manures. A second reason why the establishment could not compete with England in the price of phosphorus, might possibly be found in the circumstance that Messrs. Stark obtained from 25 to 26 cwts. of bones only 1 cwt. of phosphorus, *i.e.*, 4 per cent., while in England, 8 per cent. are extracted. The cause of this loss was that the gases on their exit from the retort, had to overcome a pressure, which, though slight, was sufficient to facilitate the escape of the vapor of phosphorus through the porous sides of the retort.

The applications of phosphorus are so numerous, that it is scarcely possible here to enumerate them all. Its greatest consumption by far is in the manufacture of matches. But it is difficult to form a correct estimate of the extent of this application. If we take as a basis the statements *Compagnie Generale des Allumettes Chimiques*, according to which the consumption in France is 360 tons, and if we assume that in the rest of Europe only double the quantity is used for the same purpose, it appears that the match trade requires the serious amount of 1080 tons, = 1,080,000 kilos. This calculation, however, is merely approximate. Nor are we able to check it either by the number of matches yearly produced or by the quantity of the inflammable mass used in their preparation, since both these factors are unknown. As regards the amount of the inflammable mixture, especially, accounts vary very widely, its proportion of phosphorus being given as low as 6 and as high as 40 per cent. Thus, according to M. Hochstätter, of Langen, 15 grms. of mass containing 7 per cent. of phosphorus suffice for 1000 matches, whilst according to M. Pollak, 31 grms. of a mass with the same percentage of phosphorus are required for the same. These discrepancies are intelligible if we consider the different sizes of the matches and the unequal bulk of their heads. As to the above-mentioned quantity, of 1080 tons of ordinary phosphorus, the amorphous must be added, which is consumed to a not inconsiderable extent, for the Swedish safety-matches, and also the comsumption for other purposes, the amount of phosphorus yearly required may be estimated at 1200 tons, for the production of which 15,000 tons of bones are consumed, if the yield is assumed at 8 per cent.

The Match Trade.—No fewer than 40 firms exhibited matches at Vienna, but not one of them has produced any decided novelty. The attempts of manufacturers have been almost exclusively directed to a pleasing appearance, the increase of production, and the reduction of price. The great bulk of matches are still made with ordinary phosphorus. Next in number, though at a great distance, follow those that can be struck only on a peculiar surface prepared with amorphous phosphorus.

Matches tipped with a mixture containing amorphous phosphorus, and capable, therefore, of being ignited on any surface, were exhibited only by one firm, H. Hochstätter, of Langen, near Frankfurt on the Main.

Matches of this kind were even displayed at the London Exhibition of 1851, but met with no approval as they were not easy to strike, and their ignition was often attended with a slight explosion and the projection of sparks. The matches of this kind exhibited by the

Viennese firm of Forster & Wawra at Paris, in 1867, still suffered from the same defects, though in a smaller degree.[1]

H. Hochstätter has finally succeeded in the complete solution of the problem, which the present reporter attempted twenty six years ago, as may be seen from the report on the matches displayed in the London Exhibition of 1872, to which he therefore refers.[11]

The reporter, at an early date, had proved by his researches on the remarkable behavior of amorphous phosphorus, with chlorate of potash and other bodies rich in oxygen, that, with phosphorus in this modification, mixtures of every degree of combustibilty might be prepared. Among the matches which were experimentally prepared with such mixtures there were always a few which satisfied every requirement. Though .the technical problem was thus by no means solved these experiments had at least proved the possibility of such a solution. To M. Hochstätter belongs the merit of having discovered the conditions for the industrial preparation, with amorphous phosphorus, of matches capable of superseding those containing the ordinary quality of phosphorus, even in the opinion of a prejudiced public, and which were capable of ignition on any at all suitable surface. The Hochstätter matches, indeed, leave nothing more to be wished for. They can be struck upon cloth; they burn quietly, without noise or spirting, almost without smoke and smell, and very rarely fail, as the reporter has convinced himself by a prolonged trial.

These matches attract absolutely no moisture, and can, therefore, be used on shipboard and in all climates. What is still more important, the workmen during their production are not exposed to danger of any kind soever; nor can they give rise to poisoning, intentional or accidental. They are also cheaper than the ordinary kind, since the mixture costs:—For those with sulphur, 0·8 shilling; for those without sulphur, 1·7 shillings; for wax tapers, 1·42 to 2·0 shillings; whilst it is stated, that, in Germany the mixtures for the same number of ordinary matches, cost respectively 1 shilling, 2 shillings, and 2·8 shillings.

---

[1] The firm of B. Forster & F. Wawra is, since 1871, known as F. Wawra & A. Kempny. It is unfortunate that this firm, one of the oldest in Austria, and the direct successor of Th. Preschel, did not exhibit. The works occupy a surface of 2381 square metres, employ 160 persons, and produce yearly 2500 millions of matches. The dextrin required in the mixture is made on the premises. The establishment has ceased making matches with amorphous phosphorus, as the demand was insufficient.

[11] Space does not allow of a repetition of the history of the match trade. It may be found in A. W. Hofmann's "Report" for 1862, that of the writer for the same occasion: in the copious "Report" of Dr. Holdhaus on matches in the Paris Exhibition of 1867, ; and in the "Report" of the General Direction on Matches and Explosives at the Vienna Exhibition of 1873. See also Thiel's paper in *Wagner's Jahresber.*, 1866, 747.

The manufacture of these matches is, without doubt, the greatest improvement which has been effected in this trade since 1862, and the question now arises, in how far it has become the serious duty of governments to listen to the many and important voices, which for years, though unfortunately in vain, have urged the banishment of ordinary phosphorus from the match trade. Half measures—such as improved ventilation in factories, and the prohibition of glue in the composition of the mixture, because in that case it must be used hot—remove the evil only partially, or not at all. An attempt has been made to lessen the danger to which the workmen are exposed by reducing the proportion of phosphorus to a minimum. How effectual such endeavors have hitherto been, appears from the circumstance that in some works even yet, mixtures are employed with a proportion of phosphorus far exceeding the 6 or 7 per cent., which in Austria is found amply sufficient.

Dr. Letheby proposed the use of oil of turpentine for the absorption of the vapors of phosphorus, and in the works of Black & Bell, at Stratford, near London, and more recently in several German establishments, each workman wears on his breast a vessel containing this oil. But this suggestion has, by no means, removed the pernicious effects of the vapor of phosphorus, since absorption still takes place through the skin and the clothing. It is also still an open question, whether the vapors of phosphorus are rendered harmless by oil of turpentine, or if their smell is merely disguised. Such palliatives are often hurtful instead of useful. Those concerned allow themselves to be lulled into a feeling of security whilst the danger is still present.[1]

When governments find it necessary to interfere in technical arrangements, great caution is doubtless requisite, since an ill-timed regulation may increase certain evils instead of diminishing them. The question, however, now a perfect method of employing amorphous phosphorus in the manufacture of matches has been discovered, seems analogous to that of the poisonous Schweinfurt green, which governments who care for the physical well-being of their citizens, did not hesitate to prohibit when once a complete substitute had been found in the shape of the new chrome green. Moreover, the opposition of manufacturers to the introduction of amorphous, in place of ordinary, phosphorus, would not be very violent since in an establishment which employs the common kind of phosphorus, little alterations of plant would be needful.

---

[1] See W. Jettle, "Die Zündwaaren Fabrikation in ihrer Gegenwärtigen Ausbildung." Brunswick: F. Vieweg. 1871.

Ordinary phosphorus can lay claim neither to economy, nor to a superior quality of the article produced, nor to greater convenience in the manufacture. On the contrary, quite independent of its absolute innocence in all these points, the amorphous modification has the advantage. In laying out new works, there is further no occasion for costly and especial arrangements for ventilation, and for abnormally lofty work-rooms if the amorphous phosphorus is to be used.

The *Compagnie Générale des Allumettes Chimiques*, which, by a recent French law, has obtained a monopoly of the match trade, will, it is to be hoped, not fail to set in this respect a good example, as, on account of the concentration of the whole manufacture, it would be easy for it to work this improved process to advantage.

As to the composition of the mixture used in Sweden, for so-called safety-matches, which ignite only on a prepared surface, there prevails still some uncertainty, and it is possible that the formulæ used in different manufactories are not absolutely identical. According to Jettel, whose statements are based upon an analysis of the mixture performed by Kriwanek, in the laboratory of Prof. Hlasiwetz, but has been slightly modified for actual use, its composition is the following :—

Glass,	$1\frac{1}{4}$	parts.
Glue,	1	part.
Bichromate potash,	$\frac{4}{5}$	"
Chlorate potash,	$6\frac{3}{4}$	parts.
Oxide of iron,	$\frac{1}{2}$	part.
Black oxide of manganese,	2	parts.
Sulphur,	1	part.

According to Jettel, the quantity of sulphur is given too high, the cause of which may possibly be that the matches were not genuine

Swedish. Jettel considers that it should not exceed the half of the proportion as given above.

The composition of the friction-surface is :—

Glue, ...	1½ parts.
Umber, ...	1 part.
Manganese, ...	4⅓ parts.
Sulphuret of antimony, . . .	16⅖ "
Amorphous phosphorus, . . .	10 "

Gentele has subsequently examined the composition of Swedish matches, and obtained very different results. He found:—

Chlorate of potash, ...	32 parts.
Bichromate of potash, ...	12 "
Red lead, ...	32 "
Sulphuret of antimony, . . .	24 "

This mixture ignited readily upon a surface consisting of 8 parts amorphous phosphorus, with 9 parts of sulphuret of antimony.[1]

It appears from the experiments of Gentele, that slight differences in the mixtures, have little effect upon the quality of the matches, if only the preparation has been careful, *i. e.*, if the separate ingredients have been ground as finely as possible, and intimately mixed, which applies also to phosphorus matches, and to all similar mixtures. The selection and preparation of the wood are not a matter of indifference.

(To be continued.)

THE "CAMEL" ENGINE OF ROSS WINANS.

By J. Snowden Bell.

There are two American locomotives that have become historic from having given origin and name to the two classes of engines which have, to a greater extent than any others, contributed to the development and economization of railroad freight transportation. These are the "Camel," built by Ross Winans, of Baltimore, in June, 1848, for the Baltimore and Ohio Railroad, and the "Consolidation," which M. W. Baldwin & Co., of Philadelphia, constructed for the Lehigh Valley Railroad, in July, 1866. The performance of the latter was found to be so satisfactory, that the class of engines of which it is a type, has been adopted as their standard heavy freight engine by the Baltimore and Ohio, Pennsylvania, Erie, Lehigh Valley and other leading railroads in the United States, and two "Consolidation" engines of the largest size, have recently been shipped by the Baldwin Locomotive Works, to Australia.

---

[1] Gentele, *Dingl. Pol. Journ.*, ccix, 369.

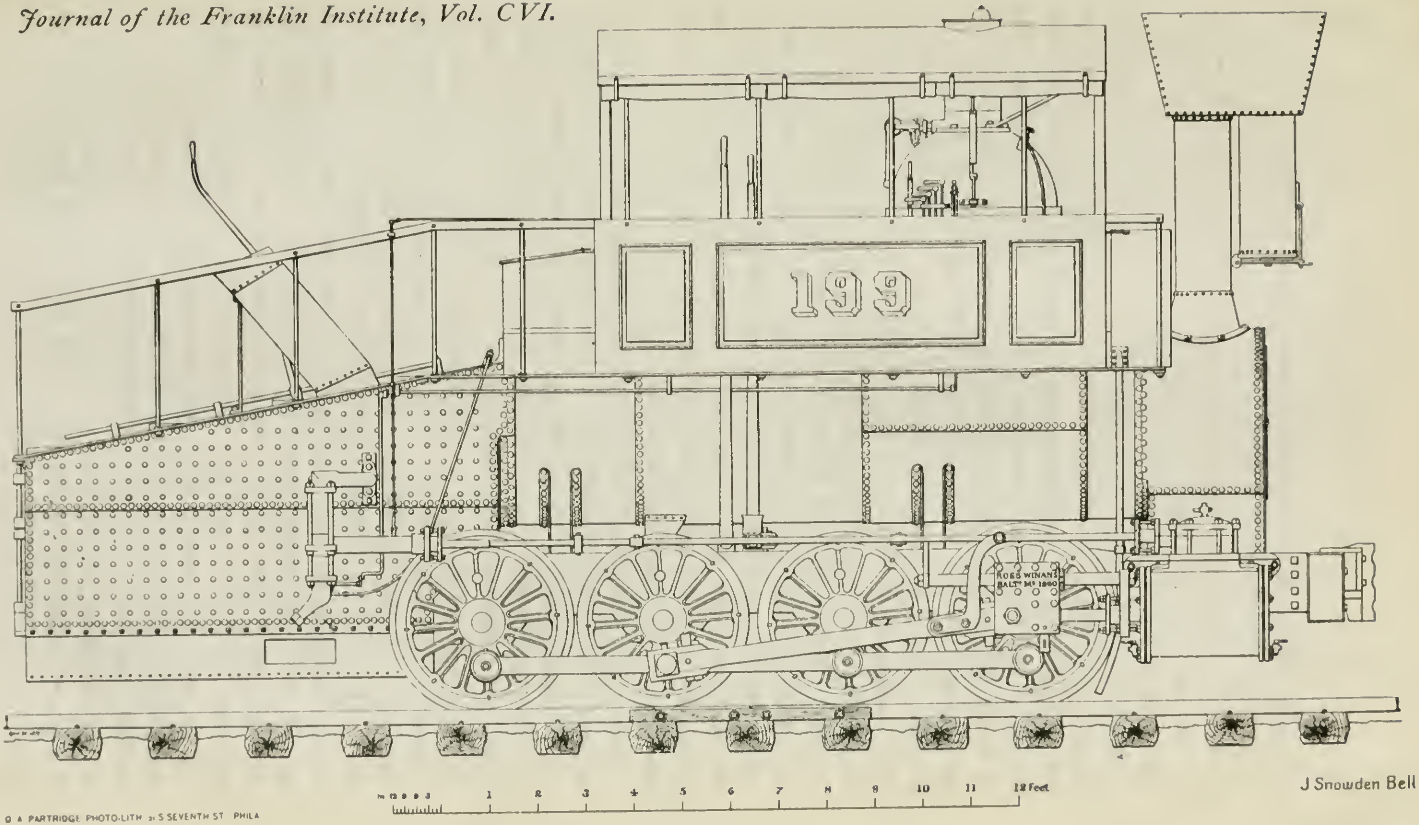
While there is obviously a wide range of difference, both as to design and detail, between the improved "Consolidation" engine of 1878, and the original "Camel" of 1848, the boldness and originality of conception, and the elements of practical value, presented at the early date of the latter, have given the "Camel" engines a prominent position in the history of American locomotive engineering, the record of which derives additional interest from the fact that their general principles, modified and improved by modern practice, are to be found embodied in the most successful type of freight engines now in use.

The first locomotives constructed in the United States with more than one pair of driving wheels, were the "grasshopper" engines of Phineas Davis, in 1834, one of which was exhibited at the Centennial Exposition. These engines had four coupled wheels of small diameter, driven from a counter shaft geared to a driving shaft rotated by two upright cylinders, and were succeeded by the "crab" engines of Gillingham & Winans, which were of the same general type, saving that they were of greater size and weight, and were provided with horizontal instead of vertical cylinders. The inadequacy of the "crabs" to fulfil the increasing demands of freight service upon heavy grades, developed the American eight-wheel connected engine, the first one of which, the "Buffalo," was built by Ross Winans, for the Baltimore and Ohio R. R., in November, 1844, and five others of the same pattern, known as "mud diggers," were made by him for the same road, between that date and December, 1846. It is not maintained that Mr. Winans was the *inventor* of the eight-wheel connected engine, but he was, without doubt, the first constructor of such an engine in the United States. M. W. Baldwin, of Philadelphia, built his first six-wheel connected engine in 1842, and it was not until 1846 that he commenced the construction of eight-wheel connected engines.

The six "mud digger" engines built by Winans, had the ordinary horizontal boiler, cylinders 17 x 24 inches, and eight driving wheels, 33 inches in diameter, coupled to a counter shaft placed immediately in rear of the fire-box and geared to the engine shaft, after the style of Gillingham & Winans' "crabs." Up to a few years past, several of them were yet in service as shifting engines, but they have all, by this time, been consigned to the scrap pile, although some of their cylinders are still doing duty in stationary engines.

The inherent defects of this type of engine, specially as compared with the Baldwin six and eight-wheel connected engines, necessitated the production of a more efficient and practical machine, and Winans' answer to this requirement was the "Camel" engine, the latest form of which is shown in the accompanying illustration. Beginning with the engine "Camel," in June, 1848, and ending with No. 219, in February, 1857, he built 119 of these engines for the Baltimore and Ohio Railroad, as well as a large number for other roads, among which were the Pennsylvania, Philadelphia and Reading, Northern Central, Cumberland and Pennsylvania, and New York and Erie. At the outbreak of the civil war, his shops in Baltimore were closed, and three of these engines in stock were subsequently purchased by the Baltimore and Ohio road, after which their manufacture was practically discontinued, a few only being made by parties by whom the shops were a short time operated.

Among the features of novelty which distinguished the "Camel" engines from prior constructions, may be enumerated the following: 1. The employment of eight driving wheels, set closely between horizontal cylinders and a long overhung fire-box, the width of which is equal to or greater than the distance over frames. 2. A fire-box having a downwardly and rearwardly inclined top. 3. A dome and engineer's house, placed on the top of the boiler, close to the forward end. 4. An upper shute for feeding coal through the top of the fire-box. 5. A fire-box having no water space on its rear side, which was closed by doors, so as to expose its entire area when required. 6. The abandonment of crown sheet stay bars, and the substitution of stay bolts, connecting the crown sheet with the outer shell. 7. The use of a half-stroke cam, as a means of effecting cut off. All these engines were substantially of the same pattern, except as to the fire-box, of which there were three classes, the short, medium and long; the latter, which is shown in the illustration, having as great a length as 8 feet, 6 inches, and a width of 4 feet. The grate surface of the medium class was 6 x $3\frac{1}{2}$ feet, giving the then enormous area of 21 square feet. The boiler, of $\frac{5}{16}$ iron, was



G. A. PARTRIDGE PHOTO-LITH. 21 S. SEVENTH ST. PHILA.

THE CAMEL ENGINE OF ROSS WINANS.

46 inches in diameter. The cylinders (except in a few of the earlier engines, which were only 17 inches) were 19 inches in diameter, and 22 inches stroke, and the diameter of the driving wheels, in all cases, was 43 inches, with an extreme wheel base of only 11 feet, 3 inches. The front and rear wheels only were flanged, and end play was left in the boxes, to admit of the passage of the engines around curves. Chilled cast iron tires were used, fastened by hook headed bolts, passing between the centre and tire, and, in the earlier engines, chilled wheels without separate tires were employed. The weight of the engines varied from 25 to 29 tons (of 2000 lbs.). The valve motion was of the old "drop hook" pattern, and the valves could be operated either by an eccentric or a half stroke cam for cutting off, as desired.

In regular service, these engines hauled eight loaded freight cars, 20 tons (of 2000 lbs.) each, up grades of 116 feet to the mile, with frequent curves of 600 feet radius, but they have, for a period of two months, performed the remarkable and probably unparaleled duty of hauling a tender and one loaded car up a grade of 1 in 10, or 528 feet to the mile, having curves of 300 and 400 feet radius, at a speed of 13 miles per hour. This was done upon a temporary track laid over the Kingwood Tunnel, on the Baltimore and Ohio Railroad, and Benjamin H. Latrobe, Esq., the engineer in charge of the work, states the total gross weight to have been 120,000 lbs., the total resistance and traction required to overcome it, 13,828 lbs., and the adhesion required $\frac{1}{4{\cdot}05}$ of the weight on drivers; further, expressing his belief that the limit of adhesion had been fully reached. Over another temporary track at the Board Tree Tunnel, having grades of 1 in 23 (229 feet to the mile), and curves of 300 feet radius, from sixty to seventy freight cars, and two passenger trains were daily taken by four "Camel" engines. Upon levels, and grades less than those before referred to, the loads hauled by these engines were equal to those of any other construction prior to the "Consolidation," and greater than most of them.

The inclined fire box was patented by Ross Winans, May 9th, 1854, and was substantially adopted by James Millholland, Master of Machinery of the Philadelphia and Reading Railroad, in two passenger engines built by him in 1859, since which time, all, or nearly all, of the engines built by that company have contained it. In 1875, the Pennsylvania Railroad adopted the "Consolidation" as their standard heavy freight and helping engine, and prepared a design, differing, in some particulars, from that of the original engine, among which was the substitution of the Winans' inclined fire-box for the wagon top fire-box used in the Baldwin Locomotive Works construction. The system of staying the crown sheet by stay bolts, connecting it with the outer shell instead of crown bars, is also adopted in the Pennsylvania "Consolidation," and is, moreover, in the "Belpaire" furnace, coming into general use in continental Europe.

The imperfections of the "Camel," both in design and construction, were many, and the class is fast going out of existence, but it has done, and to-day is doing, good service. It first practically demonstrated the superiority of the eight-wheel connected engine for heavy traffic, and while for a time the ten-wheel engine met with greater favor, the revival of the eight driver type in the "Consolidation" class, evinces that thirty years' experience endorses that demonstration. It may be urged that the two-wheel truck of the "Consolidation" is an important factor, but in the view of the writer, this is questionable. In a ~~1,000,000~~ lb. engine it carries but 12,000 lbs., and engines of this class have run satisfactorily with it removed. In the consideration of the "Camel," relatively to the "Consolidation" type, it must be remembered that after due allowance for the lapse of time between them, and the perfection of detail and workmanship in the later engine due thereto, it is the comparison of a 60,000 lb. and a 100,000 lb. engine, and a 19 x 22 inch cylinder against a 20 x 24 inch. Each of them is a credit to its designer and his time, and the reviewer of thirty years hence will doubtless have before him a structure which will make the "Consolidation," like the "Camel," a thing of the past.

Heat of Molecular Rotation.—Hermann Herwig has examined the development of heat which arises in consequence of the rotation of molecular magnets, or of electrolytic molecules. The phenomenon was first observed by Joule, and has been attested by others, but no direct investigations have hitherto been instituted to determine its precise character. Herwig's experiments show that, after eliminating the influence of induction currents, there is a considerable quantity of residual heat, which is due to molecular rotation.—*Ann. d. Phys. u. Chem.* C.

A NEW SYSTEM OF ELECTRIC LIGHTING.

By Profs. Elihu Thomson and Edwin J. Houston, of the Philadelphia Central High School.

Having been engaged in an extended series of experimental researches on dynamo-electric machines, and their application to electric lighting, our attention has been directed to the production of a system, that will permit the use of a feebler current for producing an electric light than that ordinarily required, or, in other words, the use, when required, of a current of insufficient intensity to produce a continuous arc. At the same time, our system permits the use of a powerful current, in such a manner as to operate a considerable number of electric lamps placed in the same circuit.

As is well known, when an electrical current, which flows through a conductor of considerable length, is suddenly broken, a bright flash, called the extra spark, appears at the point of separation. The extra spark will appear, although the current is not sufficient to sustain an arc of any appreciable length at the point of separation.

In our system, one or both of the electrodes, which may be the ordinary carbon electrodes, are caused to vibrate to and from each other. The electrodes are placed at such a distance apart, that in their motion towards each other they touch, and afterwards recede a distance apart which can be regulated. These motions or vibrations are made to follow one another at such a rate, that the effect of the light produced is continuous; for, as is well known, when flashes of light follow one another at a rate greater than twenty-five to thirty per second, the effect produced is that of a continuous light. The vibratory motions may be communicated to the electrodes by any suitable device, such, for example, as mechanism operated by a coiled spring, a weight, compressed air, etc., but it is evident that the current itself furnishes the most direct method of obtaining such motion, as by the use of an automatic vibrator, or an electric engine.

In practice, instead of vibrating both electrodes, we have found it necessary to give motion to but one, and since the negative electrode may be made of such size as to waste very slowly, motion is imparted to it, in preference to the positive. The carbon electrodes may be replaced by those of various substances of sufficient conducting power.

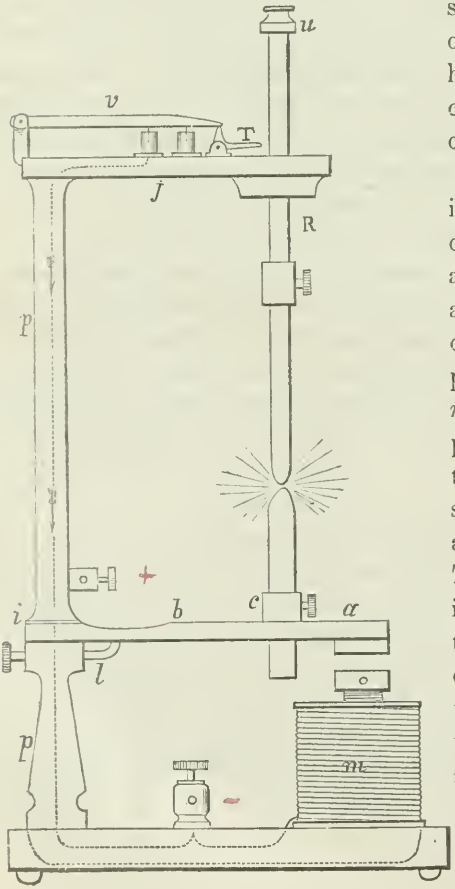
In this system, when desired, an independent battery circuit is employed to control the extinction and lighting of each lamp.

PHILADELPHIA, *Sept.* 19*th*, 1878.

A NEW ELECTRIC LAMP.

By Profs. ELIHU THOMSON and EDWIN J. HOUSTON, of the Phila. Central High School.

FIG. 1.



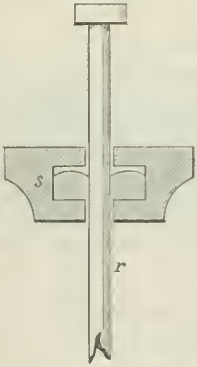
The following is a description of one of the forms of electric lamp which we have devised, to be used in connection with our system of electric lighting:

A flexible bar, *b*, of metal is firmly attached at one of its ends to a pillar, *p*, and bears at its other end an iron armature, *a*, placed opposite the adjustable pole-piece of the electro-magnet, *m*. A metal collar, *c*, supports the negative electrode, the positive electrode being supported by an arm, *j*, attached to the pillar, *p*. The pillar, *p*, is divided, by insulation at *i*, into two sections, the upper one of which conveys the current from the binding-post marked +, to the arm, *j*, and the rod, *r*, supporting the positive electrode.

The magnet, *m*, is placed as shown by the dotted lines, in the circuit which produces the light. The pillar, *p*, is hollow, and has an insulated conducting wire enclosed, which connects the circuit-closer, *v*, to the binding-post, marked —. The current is conveyed to the negative electrode, through *b* and the coils of the magnet, *m*. When the electrodes are in contact, the current circulating through *m* renders it magnetic and attracts the armature, *a*, thus separating the electrodes, when, on the weakening of the current, the elasticity of the rod, *b*, again restores the contact. During the movement of the negative electrode, since it is caused to occur many times per second, the positive electrode, though partially free to fall, cannot follow the rapid motions of the negative electrode; and, therefore, does not rest in permanent contact with it. The slow fall of the positive electrode may be insured either by properly proportioning its weight, or by partly counterpoising it. The positive electrode thus becomes self-feeding.

The rapidity of movement of the negative carbon may be controlled by means of the rigid bar, *l*, which acts, practically, to shorten or lengthen the part vibrating.

Fig. 2.



In order to obtain an excellent but free contact of the arm, *j*, with the positive electrode, the rod, *r*, made of iron or other suitable metal, passes through a cavity, *s*, Fig. 2, filled with mercury, placed in electrical contact with the arm, *j*. Since the mercury does not wet the metal rod, *r*, or the sides of the opening through which it passes, free movement of the rod is allowed without any escape of the mercury. We believe that this feature could be introduced advantageously into other forms of electric lamps.

In order to prevent a break from occurring in the circuit, when the electrodes are consumed, a button, *v*, is attached to the upper extremity of the rod, *R*, at such a distance that when the carbons are consumed as much as is deemed desirable, it comes into contact with a tripping lever, *t*, which then allows two conducting plugs, attached to the bar, *v*, to fall into their respective mercury cups, attached, respectively, to the positive and negative binding-posts by a direct wire. This action practically cuts the lamp out of the circuit.

Philadelphia, *Sept.* 19*th*, 1878.

ZIMMERMANN'S STEAM-ENGINE.

By J. H. Cooper.

One of the useful novelties of the present Exposition Universelle, is a horizontal steam-engine, with variable cut-off, controlled by a ball governor and provided with a condensing apparatus on Zimmermann's system, and constructed and exhibited by Messrs. Lecointe and Villette, Saint Quentin, Aisne. From advanced information we give description, illustration and test.

This engine has four double-seated valves, two arranged for foreclosing the admission of steam, and two held open during most of the stroke, by the working gear, for the exhaust; all are placed close to the ends of the cylinder, two above and two below. The admission-valves are controlled by a style of cut-off totally new and perfect, the invention of Mr. Zimmermann, engineer at Marchiennes, Belgium.

This engine offers the following advantages:

Great simplicity of parts, not liable to derangement.

The valves and their seats are of cast steel, the bridges of tempered steel, all of which last a very long time, the wearing of these parts being nearly nothing.

The valves and their seats are independent of, and detachable from, the cylinder casting.

The cylinder is provided with a steam-jacket, and is further protected from cooling by a wooden covering.

The governor is very sensitive, acting promptly on the valve-gear during the run of the engine.

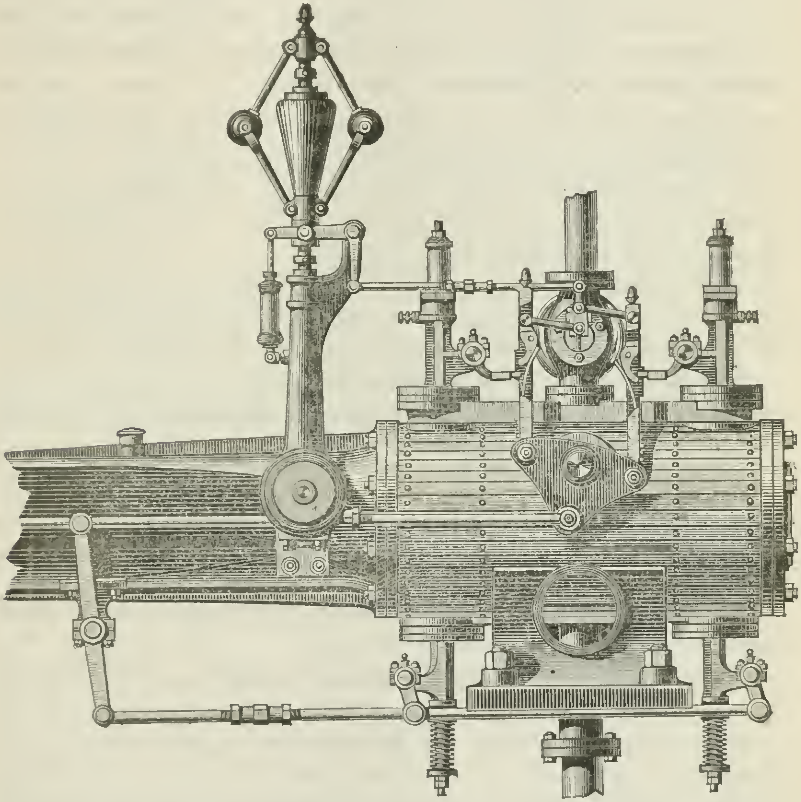
The cylinder and valves are lubricated through one cock, in the usual way.

This engine recommends itself for solidity, elegance, ease of maintenance, regularity of motion, and great economy of fuel.

Its construction throughout is of the best, and the material employed of the first quality.

The following are the results of trials made by a Prony brake and the indicator, on June 29th and 30th, 1877, by Mr. L. Pinrger, Professor in the Polytechnic School at Aix-la-Chapelle, on a steam-engine of 100 (98·63 English) effective horse-power, at work in the cloth factory of Mr. T. F. Mayer.

The engine has valves with automatic variable trip, controlled by a governor on Zimmermann's system. The effective pressure of the steam was 5 kilogrammes (11 pounds), with an absolute pressure of 6 atmospheres; the fly-wheel shaft making 51 revolutions per minute. The cylinder is furnished with a steam-jacket. The stroke of piston is 1·05 metres (41·34 inches); consequently, the mean speed of the piston per second is 1·785 metres (5·85 feet). The cylinder is ·5 metre (19·685 inches) internal diameter. The piston-rod passes through both cylinder-heads—its diameter is 85 millimetres (3·346 inches). The useful surface of piston is then 1906·75 square centimetres (295·546 square inches).



By means of a Prony brake, acting on a pulley of ·7 metre (27·559 inches) diameter, and keyed on the fly-wheel shaft, there was produced, in tightening the bolts of the brake, a useful work of exactly 100 (98·63 English) effective horse-power.

During this time a sufficiently great number of diagrams were taken by means of a Richard's indicator, at the two ends of the cylinder. 30 of these diagrams, 15 of which were taken at the front, and 15 at the back end, were used to determine the indicated power of the engine. The surfaces of all these diagrams were measured with the greatest care, by means of an Amsler's planimeter. These 30 diagrams have given the following mean results :

Length of admission into cylinder, 19·86 per cent. of the stroke.
Absolute pressure during admission, 5·76 atmospheres.
Absolute pressure of steam at end of stroke, 1·025 atmospheres.
Back pressure in cylinder, ·16 atmosphere.
Pressure in condenser, ·118 atmosphere.
The mean useful pressure of steam on piston, per square centimetre, 2·5175 kilogrammes (35·72 pounds per square inch).

Consequently, the force in indicated horse-power, while there was, shown by means of the Prony brake, 100 (98·63 English) effective horse-power, is $= \frac{2{\cdot}5175 \times 1906{\cdot}75 \times 1{\cdot}785}{75} = 114{\cdot}3$ (112·73 English), and the useful effect of the engine is $= \frac{100}{114{\cdot}3} = 0{\cdot}875$, or $87\frac{1}{2}$ per cent.

In taking account of the waste spaces, the consumption of steam in the cylinder, for a useful effect of 100 (98·63 English) horse-power per hour, is 850 kilogrammes (1870 pounds). In counting on a loss of steam coming from condensation in the cylinder and in the ports, of 50 kilogrammes (110 pounds), there results a total consumption of steam of 900 kilogrammes (1980 pounds). That is to say, 9 kilogrammes (19·8 pounds) per hour per effective horse-power.

In admitting that 1 kilogramme (2·2 pounds) of coal produces 8 kilogrammes (17·6 pounds) of steam, the consumption of coal per hour per effective horse-power, would be 1·125 kilogrammes (2·475 pounds), or ·985 kilogramme (2·167 pounds) per indicated horse-power.

The temperature of the injection-water in the condenser is 16·5° Cent. (61·7 Fahr.), the temperature of the discharge-water of the condenser 37·5° Cent. (99·5 Fahr). The quantity of water brought to the condenser $= \frac{600}{21} =$ 28·57 kilogrammes (62·85 pounds). That is to say, the condensation of 1· kilogramme (2·2 pounds) of steam absorbed 28·57 kilogrammes (62·85 pounds) of water.

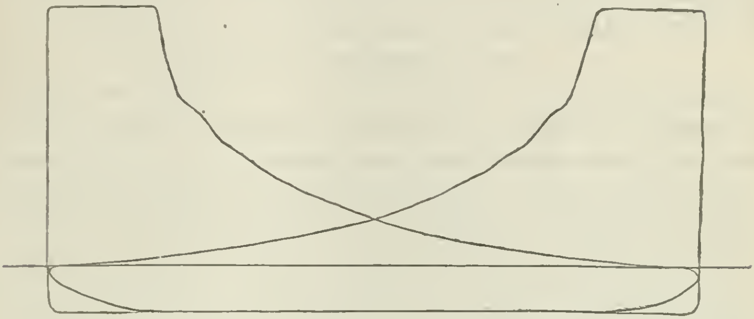


Diagram taken on the engine developing 100 (98·63 English) horse-power, effective under the action of the Prony brake.

From the diagrams taken when doing no work, it results that the mean useful pressure of the steam on the piston is ·165 kilogramme per square centimetre, and the work absorbed

$$= \frac{0{\cdot}165 \times 1906\ 75 \times 1{\cdot}785}{75} = 7{\cdot}5 \text{ horse-power (7·19 English).}$$

The work of the steam in the cylinder being 114·3 indicated horse-power to produce a useful work of 100 horse-power on the fly-wheel shaft, and the empty machine absorbing 7·5 horse-power, it follows that the work due to the increase of friction, when the machine develops 100 effective horse-power, is only in the neighborhood of 7 horse-power.

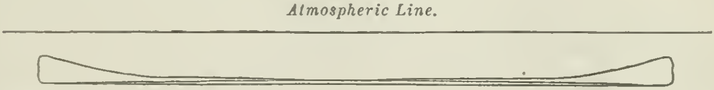


Diagram taken on the engine running empty.

This value, which should be considered as exceedingly favorable, comes from the system of distribution, by which the friction is rendered insignificant.

From what precedes, and on account of its working with perfect regularity, the construction and the performance of this machine ought to be classed as *excellent.*

STEERING OF SCREW STEAMERS.

Report of the Committee of the British Association, consisting of James R. Napier, F. R. S., Sir W. Thomson, F. R. S., W. R. Froude, F. R. S., J. T. Bottomley, and Osborne Reynolds, F. R. S., Secr., appointed to investigate the effect of propellers on the steering of vessels.[1]

Since the meeting of the British Association, held in Plymouth last year, this committee has had the satisfaction of receiving reports of the trials of various English and foreign steamers, made by the owners and officers of the steamers, without any further instigation from the committee than that contained in the circulars. These reports all show that those by whom the trials were made have become convinced of the importance of the facts which they have observed. And, indeed, the mere fact of the trials having been undertaken shows that the importance of the effect of the reversed screw on the steering while the ship is stopping herself, is beginning to be recognized. This is further shown by the fact that one of the trials was undertaken at the instance of the Court of Mr. Stipendiary Yorke, in order to ascertain if the captain of the s. s. *Tabor* had been justified in starboarding his helm in order to bring his vessel round to starboard after his screw was reversed.

All these trials, without a single exception, confirm the results obtained in the previous trials made by the committee. But this is not the most important purpose which this year's trials serve. For as regards the general effect of the reversed screw on the action of the rudder, the trials already reported, particularly those of the *Hankow* (see last year's report), are conclusive and leave nothing to be desired. But previous trials were all made with fast vessels at their full draught, their screws being well covered, and the conditions of the weather being most favorable. The trials this year, on the other hand, appear for the most part to have been made with vessels in light trim, and in two instances the wind was blowing with considerable force. The result of these circumstances on the behavior of the vessels is very decided and coincides remarkably with the effects deduced by Professor Reynolds from his experiments on models (see Report, 1875, i, p. 145), viz., that when the screw is not deeply immersed and froths the water, it exerts, when reversed, considerable influence to turn the vessel independently of the rudder; the vessel turning starboard or port according as the screw is right or left handed, which effect (and this seems to be the point most generally unknown) nearly disappears when the screw is so deeply immersed that it does not churn air into the water.

---

[1] Presented at the Dublin meeting, Aug. 19th, 1878. The *details* of the trials in 1878 are omitted.

Neither the Admiralty, the Board of Trade, nor the Elder Brethren of Trinity House have taken any further notice of these results communicated to them by the committee.

The Marine Board of South Shields has, however, taken considerable interest in the question, has invited captains to make trials, and Mr. J. Gillie, the secretary, was present at the trial of the *Tabor*, ordered by the Court, and reported the results to the committee.

There have been numerous collisions during the year, and in almost all cases the practice of reversing the screw has been adhered to. In many, if not all, instances where this has been done, the evidence goes to show that the vessel in which the screw was reversed did not turn in the direction in which those in charge of her were endeavoring to turn her. In two important cases this fact was fully apparent even to those in charge of the vessel. And in one instance the owners and captain of vessel attributed the failure to steer to its true cause, namely, the reversal of the screw; although in both cases those immediately in charge of the vessels contended that the rudder was not handled according to their directions.

The first case was that of the *Menelaus* and the pilot schooner on the Mersey. The *Menelaus* was in charge of a first-class pilot, and this steamer, in broad daylight, ran into and sank the pilot schooner, which was dropping up the river with the tide. The pilot in charge contended that owing to the wheel chains having got jammed, his orders were not attended to. The jamming of the chains was denied by the owners; and the fact that they subpœnaed the secretary of the committee to give evidence at the trial, may be taken to indicate the cause to which they attributed the collision.

The case, however, was only in part heard, for after the evidence for the plaintiffs a compromise was effected, and pilots withdrew all assertion that the wheel chains had been jammed, thus admitting that the failure to steer had been brought about by the reversal of the screw.

The other case is the well-known accident to the *Kurfuerst*. In this case it is admitted that the order was to starboard the helm and reverse the screw of the *Kœnig Wilhelm*, and this order was avowedly given with the view of bringing the vessel round to port. All the experiments of this committee, however, go to prove that with a reversed screw and a starboard helm, such a vessel as the *Kœnig Wilhelm* would have turned to starboard rather than port. This was what, according to all the evidence, did actually happen, and was the final cause of the catastrophe. But it appears that those in charge of the *Kœnig Wilhelm* arrived at the conclusion that the men at the wheel (and these would be many), although they all aver that they heard the order and obeyed it, in reality turned the wheel the wrong way. Considering, therefore, that it was not one man but a number of men at the wheel, and that the vessel behaved exactly as she would have behaved had the order been obeyed, as the men say it was, the conclusion of the Court seems to be most improbable, and for the sake of future steering most unfortunate.

The committee are now of opinion that the work for which they were originally brought together has been fully accomplished. The importance of the effect of the reversed screw on the action of the rudder has been fully established, as well as the nature of its effect completely ascertained. Also, for two years, the committee have urged the results of their work upon the attention of the Admiralty and the various marine boards, and although they regret that, as yet, they have failed to obtain that general recognition of the facts brought to light, which their vital importance demands, they consider that this will surely follow, and that as a committee they can do no more than publish the reports of the trials and the conclusions to which they have been led.

Full accounts of the experiments made previously to this year have been given in the two previous reports, and those which the committee have received this year are given at length at the end of this report. The following is a summary of the conclusions which have been established, and it is interesting to notice that the conclusions drawn by Professor Reynolds, from experiments on models, have been fully confirmed by the experiments on full-sized ships.

Summary of the results of the trials of the effect of the reversed screw on the steering during the time a vessel is stopping herself.

It appears, both from the experiments made by the committee and from other evidence, that the distance required by a screw steamer to bring herself to rest from full speed by the reversal of her screw is independent, or nearly so, of the power of the engines, but depends on the size and build of the ship, and generally lies between four and six times the ship's length. It is to be borne in mind that it is to the behavior of the ship during this interval that the following remarks apply:

The main point the committee have had in view has been to ascertain how far the reversing of the screw, in order to stop a ship, did or did not interfere with the action of the rudder during the interval of stopping, and it is as regards this point that the most important light has been thrown on the question of handling ships. It is found an invariable rule that, during the interval in which a ship is stopping herself by the reversal of her screw, the rudder produces none of its usual effects to turn the ship, but that, under these circumstances, the effect of the rudder, such as it is, is to turn the ship in the opposite direction from that in which she would turn if the screw were going ahead. The magnitude of this reverse effect of the rudder is always feeble, and is different for different ships, and even for the same ship under different conditions of loading.

It also appears from the trials that owing to the feeble influence of the rudder over the ship during the interval in which she is stopping, she is at the mercy of any other influences that may act upon her. Thus the wind, which always exerts an influence to turn the stem (or forward end) of the ship into the wind, but which influence is usually well under the control of the rudder, may when the screw is reversed become paramount and cause the ship to turn in a direction the very opposite of that which is desired. Also, the reversed screw will exercise an influence, which increases as the ship's way is diminished, to turn the ship to starboard or port according as it is right or left handed; this being particularly the case when the ships are in light draught.

These several influences, the reversed effect of the rudder, the effect of the wind, and the action of the screw, will determine the course the ship takes during the interval of stopping. They may balance, in which case the ship will go straight on, or any one of the three may predominate, and determine the course of the ship.

The utmost effect of these influences when they all act in conjunction, as when the screw is right handed, the helm starboarded, and the wind on the starboard side, is small as compared with the influence of the rudder as it acts when the ship is steaming ahead. In no instance has a ship tried by the committee been able to turn with the screw reversed on a circle of less than double the radius of that on which she would turn when steaming ahead. So that even if those in charge could govern the direction in which the ship will turn while stopping, she turns but slowly, whereas, in point of fact, those in charge have little or no control over this direction, and, unless they are exceptionally well acquainted with their ship, they will be unable even to predict the direction.

It is easy to see, therefore, that if on approaching danger the screw be reversed, all idea of turning the ship out of the way of the danger must be abandoned. She may turn a little, and those in charge may know in what direction she will turn, or may even, by using the rudder in an adverse manner, be able to influence this direction, but the amount of turning must be small and the direction very uncertain. The question, therefore, as to the advisability of reversing the screw is simply a question as to whether the danger may be better avoided by stopping or by turning. A ship cannot do both with any certainty.

Which of these two courses is the better to follow must depend on the particular circumstances of each particular case; but the following considerations would appear to show that when the helm is under sufficient command there can seldom be any doubt.

A screw steamship when at full speed requires five lengths, more or less, in which to stop herself; whereas, by using her rudder, and steaming on at full speed ahead, she should be able to turn herself through a quadrant without having advanced five lengths in her original direction. That is to say, a ship can turn a circle of not greater radius than four lengths, more or less (see *Hankow*, *Valetta*, *Barge*),[1] so that if running at full speed directly on to a straight coast, she should be able to save herself by steaming on ahead and using her rudder after she is too near to save herself by stopping; and any obliquity in the direction of approach or any limit to the breadth of the object ahead is all to the advantage of turning, but not at all to the advantage of stopping.

There is one consideration, however, with regard to the question of stopping or turning, which must, according to the present custom, often have weight, although there can be but one opinion as to the viciousness of this custom. This consideration is the utter inability of the officers in charge to make any rapid use of their rudder so long as their engines are kept on ahead. It is no uncommon thing for the largest ships to be steered by as few as two men. And the mere fact of the wheel being so arranged that two men have command of the rudder, renders so many turns of the wheel necessary to bring the rudder over that even where ready help is at hand it takes a long time to turn the wheel round and round so as to put a large angle on the rudder.

---

[1] B. A. Reports, 1876—1877.

The result is, that it is often one or two minutes after the order is heard before there is any large angle on the rudder, and of course, under these circumstances, it is absurd to talk of making use of the turning qualities of a ship in case of emergency. The power available to turn the rudder should be proportional to the tonnage of the vessel, and there is no mechanical reason why the rudder of the largest vessel should not be brought hard over in less than 15 seconds from the time the order is given. Had those in charge of steamships efficient control over their rudders, it is probable that much less would be heard of the reversing of the engines in cases of imminent danger.

ON FURTHER APPLICATIONS OF THE FLOW OF SOLIDS.[1]

By M. Henri Tresca, President of the Societé des Ingénieurs Civiles, Paris.

The author has been requested by the Institution of Mechanical Engineers to communicate a second paper on the results of his experiments on the flow of solid bodies, on which subject he read his first paper on the 11th September, 1867.

Prevented by the pressure of other affairs, he has not been able to bestow upon such researches all the attention which they merit; but hopes to be able to respond to the demand by giving expression to some useful conclusions which flow from those already formed from the first experiments.

These original facts can be clearly reconciled and harmonized with our general knowledge of the strength of materials; and more particularly with the different phases which are habitually recognized in the phenomena of compression or of extension. This connection, in some degree theoretical, has enabled the author to carry out his new investigations under entirely different circumstances, and to supply fresh evidence in their favor drawn from their character of generality.

---

[1] Paper read before the Institution of Mechanical Engineers; Paris meeting.

For all bodies two distinct periods are recognized—the period of perfect elasticity, which corresponds to variations of length proportional to the pressures applied; and the period of imperfect elasticity, during which the changes of dimensions, on the contrary, increase more rapidly than the pressures. If the second phase of deformation be alone considered, it is easily understood that it leads finally towards a condition in which a given force, sufficiently great, would continue to produce deformation, so to say, without limit—such as may be observed in the process of drawing lead-wire. This particular condition, in which the deformation is indefinitely augmented under the operation of this great force, constitutes, in fact, the geometrical definition of a third period, which has been designated by the author as the period of fluidity, and to which the greater part of his experiments on the flow of solids are related.

The period of fluidity is more extended for plastic substances; it is, necessarily, more restricted, and may altogether disappear in the case of vitreous or brittle substances. But it is perfectly developed in the case of the clays and in that of the more malleable metals.

In his paper of 1867, the author considered the deformations of these substances by flow under certain given conditions; such as the flow of a cylindrical block through a concentric orifice, or through a lateral orifice, one of the most novel subjects of his researches; also plate-rolling, forging, and punching. It was there demonstrated that in these different mechanical actions the pressure was gradually transmitted from place to place, with loss from one zone to another, in absolutely the same manner as in the flow of liquids, and with a regularity not less remarkable, but following a much more rapid law of diminution.

The pressure may be very considerable at certain points, whilst it may be nothing at all at other points, and the study of the various modes in which pressures may be transmitted constitutes, in fact, a new branch of investigation, to which M. de Saint-Venant has given the name of plastico-dynamics. It is chiefly in the operations of punching metals that this mode of transmission of pressure has been manifested, whilst the processes of forging, on their part, have afforded the means of establishing the correlation between those molecular phenomena, and the development of heat which is their direct consequence.

With respect to the formation of the jets of solid matter similar to jets of liquids, one more experiment only will be referred to, of recent date, by which the likeness is completed, and becomes absolutely illusive.

Two half discs of lead, forming portions of a cylinder 4 inches in diameter, were placed in juxtaposition in the compression-press, so as to form a whole disc. Under the pressure of the piston they resolved themselves into a cylindrical jet, identical in appearance with those jets which had previously been obtained, but formed, in reality, of two semi-cylindrical jets in perfect contact. Their surfaces of contact bore especial traces of the successive movement of the different layers, and reproduced the exact representation, in the solid state, of a sheet of water in motion.

Punching.—Regarded as a question of kinematics, the punching of various substances, as wax, clay, plastic metals, supplies instances of absolutely identical deformations. Shortly after the paper of 1867, some nuts which had been manufactured by punching hot, in England, and which were sent to the author by the kindness of Mr. Bramwell, enabled him to remark the same effects, still better developed by the phenomena of the drawing of the fibres, so well manifested in the specimens now lying on the table.

The two punches, which act in opposite directions, enter the block of metal from opposite sides, and the piece which is left between them is diminished in thickness by flowing from the centre towards the circumference, until, when the two punches are moved in the same direction, the piece reduced to a minimum thickness is shorn off and discharged outside.

The phenomena which take place in this metal, softened by heat, are such as would take place in a liquid; and they lead us to expect that the deformations observed in punching lead should be produced similarly in analogous operations on the hardest of metals.

The author had already shown the inflexion and the curving of the fibres by the punching of discs of cold iron, at the works of MM. Cail & Co.; and also the same phenomena in the burrs which were punched out; but he had not been able, on account of the insufficiency of his apparatus, to obtain, with iron, as much reduction of the height of the burr, as was obtained in his experiments with more plastic substances.

The section of one of these burrs, taken in a vertical plane through the axis, does not admit of any doubt of the deformations produced.

In a special memoir presented to the Academy of Sciences, on the 31st December, 1869, the author endeavored, on the basis of an enlargement of the burr in the zone of fluidity, as it is called, just under the punch, to establish a general formula for the measure of the reduction of the height of the burr, taking into account the whole height of the burr, its diameter, and the diameter of the punch. The height, L, was given by the formula

$$L = R\left(1 + \log \frac{R}{R_1}\right),$$

in which R and R_1 represent, respectively, the radius of the burr, supposed to be cylindrical, and the radius of the punch.

When the punch penetrates, it forces the material to spread laterally, until the moment when the solid unaltered portion below presents a less amount of resistance to shearing than is applied to the continuation of the lateral spread. This argument suffices to show that all burrs of the same section should be of the same height.

By the results of another and supplementary series of experiments, it was established that for all the different materials, subjected to the same action, the results were substantially alike, and corresponded exactly to the dimensions given by the formula.

But, at that time, the author was unable to experiment with blocks of iron sufficiently thick to embrace a range of evidence as to the reduction of the height of the burr, such as had been obtained with other materials; and it is only quite recently that the results of experiments on punching made in America have appeared, and have in a remarkable manner confirmed *a posteriori* the results of his previous investigations.

Several specimens of these punchings, very skilfully prepared by Messrs. Hoopes and Townsend, have been forwarded from the Philadelphia Exhibition, to the author. But the burrs proved a little longer than the lengths as deduced by means of the formula; the fact being that the blocks which were sent had been planed after the burrs had been punched out, to dress the faces. When the actual unplaned blocks arrived, they satisfactorily confirmed the algebraic formula.

The reduction of height seemed at first incomprehensible; and it can only be explained by the flow of a portion of the material into that of the block. It is to be remarked, too, that the lower face of the burr is convex, and the upper face is concave; with respect to the latter, the punch only crushes the material at the edge, whilst the middle of the face, notwithstanding the forced passage through the block, retains the original tool marks.

The formula is deduced, as has been seen, from certain hypotheses on the mode in which pressures are transmitted; and though it be only a particular case of more general formulæ, cited in the author's memoir on punching, it retained somewhat of an empirical character. Thanks to the researches of M. Boussinescq, in his theoretical essay on the equilibrium of pulverulent masses compared with that of solid masses, it takes its place as a rational formula, and it may therefore be accepted with complete confidence.

In one specimen only of all those which have been prepared by Messrs. Hoopes and Townsend, the pressure exerted by the flow of the metal has burst the block, and, on a close examination of the bottom of the cavity formed by the punch, in consequence of the mode by which the pressure was transmitted, all the features of the results of the explosion of a projectile there may be found.

A few more sketches of punched blocks are added. showing precisely the contortions produced in the lines of junction by the passage of the punch.

It would be unpardonable if, on this occasion, no mention were to be made of the remarkable experiments on iron compressed when cold, the results of which have already been presented at the Vienna Exhibition, and which have, until now, been only received with doubt, and even with incredulity.

Can the quality of iron really be improved by cold-compression?

There is no longer room for doubt as to this, in view of the recent researches of Professor Thurston, and the numerous specimens which are to be found in the collection of Messrs. Hoopes and Townsend, with the actual particulars of the forces under the action of which they were ruptured.

Speaking now only of the experiments with nuts when punched cold, Professor Thurston's tables indicate a considerable augmentation of resistance relatively to nuts of the same dimensions made of the same iron, and punched hot. The trials were made, either by applying to the rod which carried the nut pressure sufficient to strip the thread, or by introducing into the unscrewed nut a conical mandrel sufficiently loaded to split the nut. The augmentation of resistance due to cold punching may be taken at an average of 25 per cent.; and this result can only be explained by supposing that there is some modification of the molecular condition of the surrounding iron, which has been subjected to compression by the flow from the mass of metal driven out by the punch.

Forging.—If it be necessary to justify the expression, flow of solids, in the case of forgings, it is only needful to prove it by the inspection of a collection of specimens of rail scalings, found on the Eastern Railway, near Epernay. Each blow is in some sort represented by the formation of a wave, and drawing-out has taken place in this fashion, by the formation of successive scales for a length of several decimetres. Deformations produced by forging only differ from this mode of displacement of the molecules, in this, that they are produced for a certain purpose, and at a temperature at which the metal becomes comparatively soft.

The object of the author's early discussions on the forging of iron was to show the tendency to parallelism of all the fibres which originate in drawing-out under the hammer, and which are separated from the neighboring fibres by a cementing substance derived from the incorporated cinder, which fills up all the void spaces between the fibres. This matter is frequently of a vitreous nature, very rich in oxide of iron, and when it is not burned off or pulverized at the surface of the piece when in the hands of the smith, it follows all the varieties of form to which the piece is shaped in its several parts. It has been shown, nevertheless, that the deformation may be only superficial when the action of the hammer was mild, whilst the influence of a more powerful blow, such as is practised in industrial operations, may be felt to the core.

An oblong piece of iron may then be compared to a hank of parallel threads, which will interlock with each other when it is attempted to draw them out lengthwise, but which will separate in a much less regular manner when they are drawn in the crosswise direction, at the risk of throwing into confusion the regularity of the original arrangement; forming knots and voids which must evidently weaken the power of resistance which would be possessed by the piece under other conditions.

This effect is well exemplified by the specimen of a railing bar, in the formation of which a rectangular bar is transformed, in respect of its transverse section, into a number of rectangles and circles regularly distributed, the fibres in the circular parts losing the parallelism which is visible in the rectangular parts. This condition would certainly be critical, were it not that the central part of the enlargements was afterwards to be bored out.

The interposition of the friable silicates between the fibres which are more properly metallic, ought to be seriously taken into consideration in this case as in many others. At present a few of the more characteristic facts may be noticed.

From the fact that iron wire of good quality is capable of supporting, before giving way, loads much greater than ordinary iron, a manufacturer of best scrap iron tried to work it from piles exclusively composed of wire. A longitudinal section of the bars manufactured in this manner, having been oxidized, reveals the filiform structure of the bar much more clearly than any of the specimens of merchant bar-iron. There is exhibited a specimen taken from an old railing at the Conservatoire which broke spontaneously in its place. Having a greater proportion of the silicates in its composition, which had been imperfectly removed in the process of forging, this specimen exactly reproduces an analogous type.

On the contrary, when the best Swedish iron is submitted to the same operation, it gives but the faintest indications of longitudinal striæ, which sometimes can only be produced by taking special pains with that object.

The irons which are the most effectually purged of silicates are the best, but the expulsion of oxides formed during reheating on the surface of bars designed to be fagotted is of great importance.

The variously-colored appearances that may be raised on well-polished sections, either by a deposit of copper, or by the action of an acid, or, better still, by the action of bichloride of mercury, show clearly the arrangement of the fibres, enabling us to trace, through all the deformation of a piece, the molecular displacements which, but for that demonstration, would remain undetermined.

The treatment by a very weak solution of hydrochloric acid, first employed in the Low Countries by M. de Ruth, is so effective, that by inking the surface, indented at the parts of least resistance by the action of the acid, proofs may be taken, in which the direction of the fibres is perfectly distinguishable. By the employment of chloride of mercury, the indentations and the fibres are much more neatly and delicately defined.

Without reverting to the examples given in the first paper by the author, he will now give other instances in illustration of the most ordinary results from the fibrous constitution of the metal.

On the basis of the evidence supplied by the oxidation of polished sections of iron, M. Le Chatelier[1] sought to separate the siliceous matter which envelops the fibres of the metal, by exposing the iron, at a red heat, to a current of chlorine. The iron is volatilized by this process, and leaves a skeleton as the residue, having the form of the original piece, composed of extremely fine filaments, and resembling, more than anything else, the residue left by a match which quietly burns without inflaming, supposing that the ash is prevented from being pulverized.

This siliceous carcass scarcely amounts in weight to a hundredth part of that of the metal, but it was associated with a certain proportion of iron, which completely disappeared in the course of the operation.

It has been stated that these silicates are friable when cold; and it appears that, with the object of diminishing the wear of bearings, the journals of shafts are sometimes hammered, in order to pulverize this interposed foreign matter, and entirely to clear it away from the rubbing surface.

(To be continued.)

Microphonic Anticipations.—Clerk Maxwell looks for the day when physicians in London will examine their patients by auscultation, in any part of the kingdom; and when the entomological society, putting a microphone in a nest of scorpions under the tropics, will be able to compare their music, in the rooms of the society, with that of the nightingale or that of the cat, and thus increase the interest which has been awakened by Wood Mason's discovery of a musical apparatus in those venomous insects.—*Les Mondes.* C.

---

[1] *Comptes Rendus de l'Académie des Sciences,* tome 82, p. 1057.

THE VARIOUS METHODS OF DETERMINING THE VELOCITY OF SOUND.[i]

The propagation of sound is a question with many bearings in the province of physics, and the researches of physicists in relation to it, though numerous, have left some points still under discussion. It is useful in the view of further inquiry to be furnished with a historical survey of what has been already done, and this is the object of a recent memoir by Dr. H. Benno-Mechlenburg, published in Berlin (a *résumé* of which to the following effect appears in the May number of the *Journal de Physique*).

The author has adopted the following classification of the methods that have been employed for measuring the velocity of sound:—

I. Methods requiring the measurement of a time and a course traversed.

1. Direct measurement of the velocity; the most ancient measurements of this kind were executed by P. Mersenne in 1657, by the Academicians of Florence in 1660,[ii] by Walker[iii] (in England), in 1698; by Cassini and Huyghens (in France) etc.

2. Method of coincidences, indicated by Bosscha,[iv] and employed by Koenig.[v]

3. Apparatus of Neumann[vi] and Le Roux.[vii]

II. Estimation of the velocity of sound by the number of vibrations and the wave-length of musical sounds.

A. Direct methods:

1. Method of Bernouilli, with sonorous tubes.
2. Method of Chladni,[viii] with rods.
3. Method of Kundt.
4. Methods of Stefan[ix] and Warburg.[x]

---

[i] *Nature.*

[ii] Newton, "Philosophia Naturalis Principia Mathematicæ," II., Prop. XLVIII.—L.

[iii] Laplace, "Méchanique Céleste," t. v, livre xii. p. 115.

[iv] Tentamina, "Exper. Academ. del Cimento," 1738, xi, p. 116.

[v] *Philosophical Transactions*, 1698.

[vi] *Pogg. Ann.*, t. xcii, p. 485.

[vii] *Comptes Rendus*, t. lv, p. 609.

[viii] *Pogg. Ann.*, t. cxxviii, p. 307.

[ix] *Comptes Rendus*, t. lv, p. 662.

[x] Chladni's "Acoustics."

B. Methods based on the interference of sonorous waves:

1. Method of Savart.[i]

2. Method of measurement of the wave-length with Quincke's interference tubes.[ii]

3. Method of Zach.[iii]

4. Method of beats.

The way in which the velocity of sound is affected by certain circumstances, especially intensity and pitch, requires further elucidation. Up till recent times it was believed, in accordance with the earlier observations and the theoretical formulæ of Newton and Laplace, that sound is propagated with a uniform velocity in the same medium, the temperature remaining constant: that the velocity of sound in air at zero, *e. g.*, is an invariable quantity. After an observation by Parry related by Sir James Ross, that the sound of a cannon was always heard sooner than the word of command to fire, Schröder van der Kolck was led by theory to a formula giving the velocity of sound in a gas as a function of the relation of the two specific heats and the degree of compression of the medium. This velocity would be greater the more intense and grave the sound, and would diminish with the distance traversed.

Regnault set himself to determine rigorously the ratio of the two specific heats of gases, with a view to deducing the mechanical equivalent of heat. He remarked that Newton and Laplace had assumed, in their formulæ, that the gases were perfect, *i. e.* (1), that they followed Mariotte's law exactly; (2) that their elasticity was not altered by surrounding bodies; and (3) that gas opposes no inertia to the transmission of sound-waves. Accordingly, the propagation of sound was supposed the same whatever the intensity. Regnault's more complete formula indicated that the velocity is greater the greater the intensity of the wave.

Experiment proved that the intensity of the wave diminishes in a tube more rapidly the smaller the section. The wave is weakened by the reaction of the elastic walls of the tube, causing a considerable loss of *vis viva;* and the diminution of intensity, according to Regnault's formulæ, should result in diminution of velocity, which diminution must be more rapid the narrower the tube. This was confirmed by experiment.

---

[i] *Sitzungsberichte der Wiener Akademie*, t. lvii, pp. 197 and 708.

[ii] *Pogg. Ann.*, t. cxxxvi, p. 285.

[iii] *Comptes Rendus*, t. vii, p. 1068.

As regards experiments with the human voice and wind-instruments, the following are the principal observations of Regnault: acute sounds are propagated with much less facility than grave sounds; in very wide pipes, it is necessary to sing with a baritone voice in order to be well heard; the fundamental sound is heard before its harmonics, which succeed in order of pitch, and the timbre is thus altered. The velocity was found independent of pressure, as indicated by the formulæ. Lastly, with different gases, the velocities are inversely proportional to the square roots of the densities.

In connection with the foregoing, it is interesting to compare the results that have been obtained by Kundt.[1] The idea of his method was suggested by Chladni's figures. A tube of glass is used about 2 m. long, containing a certain quantity of lycopodium powder (distributed as regularly as possible), and closed at the two ends. You rub the tube longitudinally, so as to produce a sound. The powder is then seen to accumulate at the nodes of vibration, so that the sonorous waves of the gas are, in a way, rendered visible. The distance from one node to the next being half a wave length, suppose that we have twelve in the tube; the length of the tube vibrating transversely will be the half of a wave-length in the *glass*. Under such conditions, then, the length of half a wave in the glass is sixteen times the length of half a wave in the air. It will follow that the velocity of sound in the glass is sixteen times that in air. Other gases may be used in the tube, and the velocity of sound similarly found in them.

By a simple modification of the apparatus, this method gives the velocity of sound in a large number of solid bodies, and the results agree pretty closely with those found by different methods.

But Kundt's method does not give sufficient precision in respect to the delicate questions investigated by Regnault. The wave-lengths measured never go beyond about 45 mm., making the 0·0001386 part of the course traversed by sound in a second; hence an error of 0·1 mm. made in the measurement of a wave-length would lead to an error of $\frac{11}{15}$ m. in the result sought. With this reserve, Kundt's results may be here noted.

---

[1] *Pogg. Ann.*, t. v, p. 496.

1. The length of sonorous waves, and consequently the velocity of sound, diminishes proportionally to the diameter of the tube, when this is less than a quarter of the length of undulation.

2. In narrow tubes a high sound is transmitted more rapidly than a grave one, and the diminution of the velocity of sound is in inverse ratio to the wave-length.

3. The velocity of sound is independent of the pressure in a wide tube, but increases with it in a narrow one.

It will be seen that these latter results are in contradiction with those found by Regnault.

It may be generally affirmed that every influence which tends to increase the *vis viva* of the molecules of the sonorous medium has an accelerating action on the velocity of sound, and every influence tending to diminish the *vis viva* diminishes also the velocity.

The causes affecting the velocity of sound are, it is shown, various.

In an indefinite medium they are:

1. The temperature of the medium; 2. The quantity of foreign substances found in it, *e. g.*, water-vapor; 3. The pitch of the sound; 4. The direction and force of the wind; 5. In solid bodies, the direction of the sound in relation to the molecular structure.

In sonorous tubes:

6. The diameter; 7. The curvature; 8. The rugosity of the interior surface; 9. The thickness of the walls.

The action of the following additional causes is still disputed:

1. The intensity of the sound; 2. The length of course traversed; 3. The substance forming the tubes.

There is complete disagreement between Regnault, Schröder, Kundt, and Seebeck, as regards the influence of the pitch of the sound. Regnault affirmed merely that an acute sound is transmitted more easily, but not more rapidly, than a grave sound; Schröder finds that the velocity diminishes as the acuteness increases; Kundt and Seebeck reach the contrary result. Fresh experiments are required to settle this important question.

ELECTRICAL LAMP WITH CONTINUOUS CIRCUIT, FOR WORKING IN THE OPEN AIR.[1]

By EMILE REYNIER.

Translated for the JOURNAL OF THE FRANKLIN INSTITUTE, from *La Nature*, by P. PISTOR, M. E.

If a very intense current of electricity is led through a resisting and refractory conductor, such as a pencil of carbon, the temperature of this conductor may rise to a dazzling white heat; it then emits a vivid light. This is the well-known principle of electrical lamps.

The principal difficulty to be overcome in the electrical lamp, is to limit the undue waste of the luminous conductors; a waste which is very rapid even in an enclosed space, on account of the volatilization and disaggregation of the carbon pencils; and which is greatly accelerated in the open air, by the rapid combustion of the incandescent carbon.

In the various systems of electrical lamps with continuous conductors heretofore proposed, the renewing of the carbon points is performed in the following manner: The incandescent pencil is placed in the circuit, with fixed contacts, and remains part of the same until broken by being consumed. The light is then extinguished. The current now suddenly passes from this carbon to another, which is consumed, the circuit broken in itsturn, and so on.

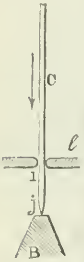
This method is open to many objections; there is an interruption of the current accompanied by an extinction of light at every rupture of the pencil. The luminous intensity varies continually on account of the gradual thinning of the carbon. The conductor only gives its maximum of light at the moment next to that of rupture. Finally, the proposed apparatus can scarcely work except in an enclosed space.

In the new system which forms the subject of this communication, the renewal of the carbon is progressive. The carbon, incandescent a part of its length, advances almost continuously, till the whole available part has been consumed. This system can operate in the open air. The following is the principle: A cylindrical or prismatical pencil of carbon, *C*, Fig. 1, between *i* and *j*, forms part of an electrical circuit (continuous or alternate), sufficiently intense to render this part incandescent. The current enters or leaves at the point of contact, *l*, it leaves or enters at the point of contact, *B*. The contact *l*, which is elastic, compresses the pencil laterally; the contact *B* touches it at its end. Under these conditions the carbon is consumed at its extremity sooner than at any other place, which tends to diminish its length. Consequently, if the carbon is steadily forced in the direction of the arrow, it will gradually advance as it is consumed, sliding through the lateral contact *l*, so as to press continuously on the point of contact at *B*. The heat developed by the passage of the current is greatly increased by the combustion of the carbon.

---

[1] Resume of a communication to the French Physical Society, at the meeting of May 17th, 1878.

Fig. 1.



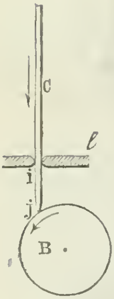
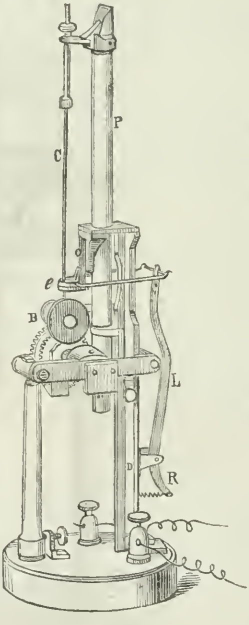


Fig. 2.

Fig. 3.



In practice I substitute for the fixed contact a revolving contact *B*, Fig. 2, which carries off the cinders of the carbon. The rotation of the contact is made dependent on the progressive movement of the carbon, so that the weight of the latter exerted at its end, acts as a brake on the mechanism of the motion.

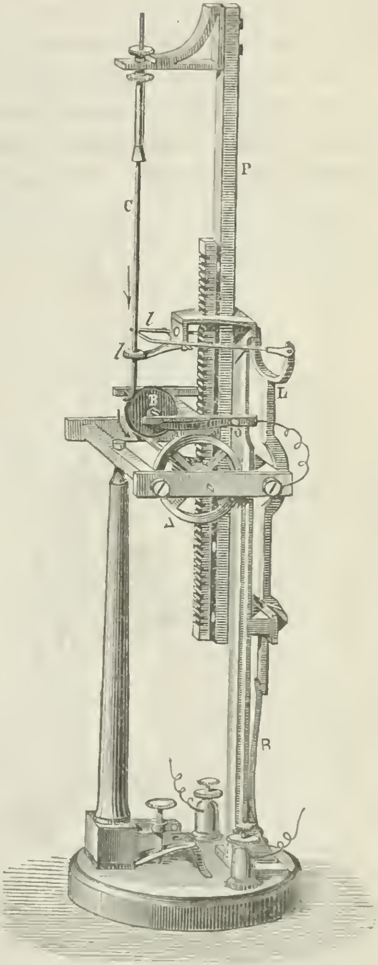
The principle of this new system once established, simple apparatus to realize it could easily be devised. The specimens I submitted to the Society of Physics, may be understood at the first glance. The advance of the carbon *C*, Fig. 3, and revolving contact at *B*, are obtained by means of the descent of the heavy rod *P*. To wind up the lamp, it is only necessary to raise this rod. The carbon pencil is placed in its position without any adjustment. The luminous point remains fixed, which is always advantageous, and particularly so in optical experiments.

This apparatus gives a clear white light with four Bunsen elements. With a more powerful electrical source, several lamps of this system may be operated, and thus "a subdivision of the electrical light may be obtained."

I have made the following experiments before the Society of Physics: with a battery of 36 elements of 18 centimetres, grouped in two series of 18 each, I have operated "four" lamps placed in a "single" current. I have at will repeatedly extinguished and re-lighted the four lamps. Each of the four lamps could be extinguished and re-lighted "individually," the three others continuing unaffected. Light has been obtained from one of these lamps by means of the current of a small Gramme Machine for the laboratory with treadle attachment.

Finally, a fine light has been obtained with a battery of three Planté (secondary), elements which were charged during the afternoon, at the establishment of M. Bréguet, and carried, charged, to the hall of the society. I remarked that this experiment may be considered as a step towards the application of the electrical light to "domestic purposes."

Fig. 4.



I will close by describing a new and unpublished mechanical arrangement of my apparatus.

In this arrangement the revolution of the turning contact is obtained from the tangential component of the pressure of the carbon pencil on the circumference of the disc; thus the end of the pencil never leaves the revolving contact, and all causes of irregularity in the light are obviated.

The brake, always indispensable, is operated, Fig. 4, in the following manner: the disc *B* is carried by a lever swinging from *O;* the pressure exerted by the carbon on the disc *B*, causes the shoe *S* to press on the face of a wheel *A*, which is revolved by means of the weight of the heavy rod *P* through its rack and the pinion *a*.

Accordingly, as the point of the luminous conductor presses more or less heavily on the disc, the brake will retard, more or less, the descent of the heavy column, which occurs at almost inappreciable intervals.

This new arrangement differs from that presented to the Academy of Sciences (session of May 13th), and to the Society of Physics (session of May 17th).

WIRE ROPE TRANSPORTATION.

Der practische Maschinen-Constructeur gives a very full description of a system of rope transportation as constructed by the "Tramway Company, limited," but considerably modified by Franz. Schingen, C. E., of Düren.

Transportation by means of a wire rope as a feeder to the main lines of railway, is calculated to supply a want long felt. The time and capital necessary for its construction, as well as the expense of operating and keeping it in repair, are considerably less than those of other systems. The use of a wire rope for this purpose is not new, but it has generally been used merely as a support and guide for the wheels carrying the load; the necessary power being supplied on an incline by the weight of the load, by an independent propelling rope, or, finally, by hand-power.

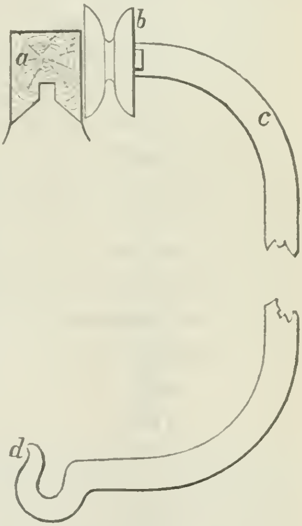
The difficulty of passing the load over the supports has been the chief cause of its failure as a combined means of support and propulsion. The regulating of the motive power was also impossible, as the load, unevenly distributed over the rope, caused a sagging of the same between the support, and, consequently, alternately exerted a force in the same direction, and then against the propelling power.

These difficulties have been overcome by adopting (1) an endless wire rope, moving over supporting rollers; (2), a distribution of the load on several carriers, instead of one, following each other at regular intervals.

It is thus possible to equalize the opposing strains caused by the sagging of the rope on either side of the support, and also to obtain a steady motion. The greater the number of carriers on the rope, and the more even their distribution, the steadier the motion. A complete set of working drawings accompany the article.

To obtain the necessary friction, the rope first passes over the traction pulley, then over a tension pulley, and, finally, over a loose pulley on the shaft of the former. The last two pulleys have flanges and a wooden facing. The tension pulley is held in place by counterweights attached to a rope passing over rollers. The weights rise and fall, according to the strain on the rope. The whole arrangement rests on a wooden frame, which should be built on a stone foundation, with anchor bolts passing through, on account of the many jars which cannot be avoided, especially when starting the rope. The arrangement for unloading is as follows: A heavy frame carries four pulleys, two on each side, a tension and a guide pulley. The slack side of the rope runs first under the tension, and then over the guide pulley. The tension side first over the guide, then under the tension pulley. Near the centre of the guide pulleys, on both sides of the frame, are two rails of flat iron, on edge, bent so as to incline down and join below the rope, so that the carrier may be run over to either side of the rope. When the wheels take the rails, the carrier leaves the rope, and it is switched off in this manner.

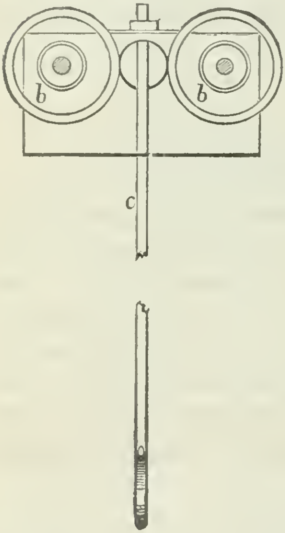
Fig. 1.



The station for loading is similar to the above. As the rope is to return from this point, it is led over a guide pulley, then over one inclined in such a manner as to lead on to the second guide pulley. The arrangement of the rails for running the carrier off the rope, is the same as before.

The carrier is composed of two blocks of wood, *a*, Figs. 1 and 2, sheathed in iron, linked together, each having a groove its entire length, and two small double-flanged wheels, *b*, on one side. A bent iron rod, *c*, from each block carries the suspended load. The wheels of the loaded carrier rest on the rails at the station. It is allowed to roll down the incline, the block slides on to the rope, which immediately presses itself so tightly into the closely-fitting groove that, even when passing over the supporting pulleys, it does not leave the groove, whose slanting sides fit closely over the rim of these pulleys. There is, consequently, no danger of the load sliding when traveling up the sag of the rope. Arrived at the station to unload, the wheels take the rails, which reach their highest level at the guide rolls. The rope, immediately after passing over these, parts with the block, the tension pulley carrying it downwards. The empty carrier is run onto the rope, slack side, in the reverse manner to return.

Fig. 2.



The rope is carried around curves by means of vertical and horizontal guide pulleys, the number of which depends on the angle of curvature. It is claimed that a curve of 8 ft. radius, for the inner rope, is practicable, though it is advisable to take a larger radius if possible. In order to pass the carrier around the curve, it is run off the rope in the same manner as at the unloading station, passes around the curve on the inclined rails, and drops on to the rope automatically. Branch roads can be constructed in the same manner, and the carriers transferred from one line to the other by means already described.

It is not advisable to make the supports more than 23 ft. in height. A heavy grade (1 : 6) is not objectionable. The guide pulleys should be carefully lined up. Their diameter depends on the size of the rope, and this, finally, on the load to be transported. P.

Velocity of Steamships.—Since 1840 the Atlantic steamers have increased their speed from 8·3 knots per hour to 15·6 knots, while the supply of fuel per 100 horse-power has been reduced nearly 60 per cent. In 1877, there were 182 steamers in service, with a freight capacity of 556,560 tons.—*Fortsch. d. Zeit.* C.

Work of Diffusion.—Preston thinks that the mechanical labor accomplished in the diffusion of gases is at variance with the second law of thermodynamics, inasmuch as it involves a transfer of heat from a colder to a warmer body. Clausius replies that if that transfer was so made as to restore the variable material at the close of the process to its original relations, the objection would be good. But this is not the case. The two gases at the beginning are unmixed, and at the close they are mixed. During the mixture there is an evident change, accompanied by an expansion of the gases, and it is in consequence of this expansion that the apparent reversal of the law takes place.—*Ann. der Phys. u. Chem.* C.

The Planet Vulcan.—The observation of an intra-Mercurial planet by Profs. Watson and Swift, naturally awakens an interest in the determination of its distance from the sun. The only data upon which an estimate of the distance can be based, are the group of supposed observations which Leverrier used in his calculations of the perturbations of Mercury, and the harmonic prediction which was communicated to the American Association, in 1873, and strikingly confirmed by the sun-spot observations of De la Rue, Stewart and Loewy. Mouchez and Gaillot, in communications to the French Academy, estimate the probable period of revolution at 24·25 days, thus making the orbital time somewhat less than that of solar rotation.—*Comptes Rendus.* C.

Zodiacal Light and Sun-Spots.—Among the most important results of the observations upon the recent solar eclipse, are the evidences of a connection between the brilliancy of the corona and the number of sun-spots, and the indications of a meteoric action within the corona. Cassini observed that the zodiacal light is most brilliant when the sun has large and numerous spots. Olbers, in a letter to Grinthuisen, published in his Astronomisches Jahr Buch for 1840, says that his grandson, Wilhelm Focke, had observed an unusual brilliancy in the zodiacal light in the early part of 1839, when the sun-spots were very numerous. These combined observations seem to lend confirmation to the meteoric theory of the zodiacal light.—*Les Mondes.* C.

Bismuth Bronze.—A bronze, composed of 52 parts copper, 30 parts nickel, 12 parts zinc, 5 parts lead, and 1 part bismuth, resists oxidation, and is especially fitted for the preparation of mirrors, lamp reflectors, etc.—*Fortsch. der Zeit.* C.

Hot Air and Steam in Puddling Furnaces.—Lemut describes an apparatus for combining hot air and superheated steam in puddling furnaces. The grates, the sides of the fire-boxes and of the ash-pit, and all the hottest portions of the apparatus, are connected with air-chambers, which are so supplied with vapor as to increase their durability, and at the same time to furnish an ample quantity of air for the draft, heated to a temperature of from 450° to 500°. By means of this elevated temperature he has been able to introduce superheated steam under the grate, and to realize an important saving by its decomposition. The total saving effected by his apparatus, he estimates at more than 25 per cent.—*Ann. des Mines.* C.

Non-existence of Electric Elongation.—Edlund, in 1866, and Streinitz, in 1873, concluded that a conductor, when traversed by an electric current, was lengthened in consequence of the electric influence. Wiedemann regarded their experiments as inconclusive and the question as an open one. Blondlot, by examining the phenomena both in the lateral and in the longitudinal direction, concludes that the phenomena are due entirely to heat, and that the passage of an electrical current in a metallic conductor produces no mechanical effect of lengthening or of shortening. His apparatus was so sensitive, that a variation of ·00025 mm. would have been sensible.—*Comptes Rendus.* C.

Variations of Terrestrial Magnetism.—M. Quet, starting from the hypothesis of an artificial earth, suitably constructed in regard to the conduction of electricity and magnetism, turning upon its axis and revolving about a sun which diffuses electrical currents, calculates the result which ought to ensue. Applying the general principle of La Place, that the state of a system of bodies becomes periodic when the effect of the primitive conditions of movement has disappeared by the action of resistances, he finds that the diurnal and annual variations, and the opposition in the character of the variations in the northern and southern hemispheres, should all be such as have been actually observed.—*Comptes Rendus.* C.

Early Use of Iron.—The oldest pieces of wrought iron which are known are, probably, the sickles which were found by Belzoni under the pedestal of the sphynx in Karnac, near Thebes; the blades which Wyse found imbedded in the wall of the great pyramid, and the piece of a saw which Layard dug up at Nimroud. These remains are now owned by the British Museum.—*Fortsch. der Zeit.* C.

Combination by Volumes.—Schröder generalizes his investigations upon volume combination, as follows: The volumes of different bodies stand in simple relations; *A*, for gases, as is well known, under equivalent pressures and temperatures. *B*, for fluids, as he first showed in 1843, under equivalent vapor pressures, and as he has subsequently shown, under equivalent solidities of the combined elements. *C*, for solid bodies, under equivalent solidities of the assimilating elements.—*Ann. der Phys. u. Chem.* C.

Origin and Periodicity of Tempests.—Zenger (Mem. de l'Acad. des Sci. de Bohéme) has been examining a table, published by Argelander, of the tempests observed at Helsingford and Abo, between 1821 and 1831. Finding that these tempests often correspond to magnetic storms and auroras, he began, in 1875, a series of solar observations. On examining photographs of the sun, he found that in tempests the disc seemed to be surrounded by an absorbing couch, which was indicated upon the plates under the form of a circle, an ellipse, a parabola, or bands, the breadth of which varies from a semidiameter to six diameters of the sun. The appearance of this zone sometimes precedes the beginning of a storm by a day, and anticipates any barometric indications. In a journey to Tyrol and Switzerland, observations which were made at altitudes varying from 5,000 to 10,000 feet, gave similar results but still more striking than in the plain. On comparing the dates of the photographs he found that tempests seemed to occur at periods of from ten to thirteen days. Similar intervals were found in tables of American tornadoes from 1794 to 1854, and of Chinese typhoons from 1783 to 1876. The storm charts show, moreover, the existence of two great storm centres; the Island of St. Thomas, in the West Indies, and the coast of Farther India, about latitude 18° to 20°; the two centres being about 180° apart. All of the disturbances seemed to be dependent upon influences which returned at every semi-rotation of the sun.

C.

Ozone.—Eremine finds that in solutions of oxalic acid, ozone may be kept much longer than in any other fluids that have been hitherto tried. Moreover, the decomposition of the ozone, in daylight, is slower than in darkness; the ozone which has been left for some time after its preparation, has a much more energetic disinfecting power.—*Les Mondes.* C.

Mosandrum; a New Element.—Prof. J. Lawrence Smith, on September 22d, 1877, deposited a sealed packet in the French Academy, describing a new earth of the cerium group. He sent specimens of the earth to Delafontaine, Soret, and others, who examined it, some thinking that it might be the terbium of Marignac, while others supposed that it was entirely unknown. The spectroscopic observations of M. Soret demonstrated that it was formed from a new element akin to the Yttria group, to which he has given the name of Mosandrum, in honor of Mosander, the discoverer of terbium.—*Comptes Rendus.* C.

Geological Progress.—Delesse and De Lapparent, in their last geological summary, quote largely from the reports of Prof. Lesley and his assistants on the second geological survey of Pennsylvania. They mention numerous instances of the discovery of native iron in trap rocks and in dolorite, and consider that the immense masses of native iron in Greenland, are telluric instead of meteoric, resulting from a reduction by petroleum or graphite, or by the organic matters which are commonly found in basaltic and trap rocks. The investigations of Viollet Le Duc and Grad lead to the conclusion that glacial action, so far from having hollowed out valleys, has protected them from erosion. Milne thinks that the action of icebergs has been generally exaggerated, and that the depth of the submerged portion of an iceberg is rarely so great as the height of the pyramidal portion which is out of water. De la Grye has proved, by experiments made at Rochelle, that the quantity of mud at the bottom of a stream is often ten times as great as that at its surface. He has frequently found a true river of mud rolling at the bottom of the sea. Buchanan and Murray have shown that the supposed organism, bathybius, is nothing but a gelatinous precipitate of calcium-sulphate, and that there is no protoplasm in sea-water which furnishes any appreciable quantity of organic matter, except foraminiferæ and algæ.—*Ann. des Mines.* C.

Heating Wheel Tires.—In the workshops of the railway from Moscow to Nijni, the wheel-tires are plunged, by the help of a movable crane, into a metallic reservoir filled with water, which is kept boiling by the admission of steam from a neighboring boiler. After ten minutes immersion, the tire is put upon the wheel. The heat is more uniform than that which is given by fire, and the contraction is, consequently, more regular. In six years the water-treated tires only furnished one fracture, and less than one per cent. have become loosened upon the wheel.—*Ann. des Ponts et Chauss.* C.

Telephone without a Diaphragm.—Mr. F. G. Lloyd, in *Nature*, gives the following account of a very interesting experiment: Two ordinary electro-magnets—unscrewed from a couple of large electric bells—were fastened, by means of two little wooden saddles and a screw each, to a small piece of deal board about $4\frac{1}{2}$ inches square and $\frac{5}{8}$ inch thick, in such a way that the poles were all but touching. Their wires were then joined so that poles of opposite denominations faced each other, *i. e.*, north opposite south, and *vice versa*. This, placed on an empty cigar-box and four Leclanché cells in circuit, gave out the tune of a musical-box clearly and loudly in the room. When both poles were made to touch, the sound ceased: but with a thin piece of paper or stout tinfoil between them, without any intervening air space, the sound was heard. On gradually separating the magnets, the sounds grew fainter and fainter, till they became inaudible. By putting the bass-board close to the ear, whistling and singing to the microphone were very clearly and loudly heard, also the voice of the person speaking could be recognized; but words were hardly sufficiently defined to distinguish all that was said, though now and then parts were intelligible. One ot the electro-magnets was afterwards replaced by a small permanent steel horseshoe-magnet fastened to the board in a similar manner: the result was the same, but slightly louder, probably from there being less resistance. By varying the strength of battery, size, or mode of mounting magnets, or adjustment of the microphone, I have no doubt that perfect definition can be obtained. Thus it would appear that the electro-magnet, without any diaphragm whatever, can be made a reproducer of sounds transmitted by a Hughes' microphone, and thus a complete and practical telephone system produced without the possibility of infringing anybody's patent. *

PREDICTION CONFIRMED.

HAVERFORD COLLEGE, *Sept. 9th*, 1878.

Editors of the JOURNAL OF THE FRANKLIN INSTITUTE.

GENTLEMEN:—Gaillot's estimated orbit for Watson's inner planet (*Comptes Rendus*, 5 Août 1878), accords closely with the predictions which I made in 1873 (*Proc. Am. Phil. Soc.*, xiii, 238, 472). It represents the third of my harmonically-indicated intra-Mercurial planets:

	Distance.	Time.
Gaillot (computed), . . .	·164	24·25 dys.
Chase (predicted), . . .	·165	24·50 "

—Yours truly,

PLINY E. CHASE.

Book Notice.

FRICK'S PHYSICAL TECHNICS; a Manual for Experiments in Physics. J. B. Lippincott & Co., Phila., 1878.

This work, which first appeared in this country in 1861, has met with deserved commendation, as being a very useful book. Its scope was amply large enough to include all the experiments needed to illustrate a very full course of lectures on physics, and the detailed descriptions of materials used, and of methods of construction of apparatus, gave it great value. A book of this kind is especially needed by the many teachers of physics, who are out of the reach of skilled mechanics, or who have not the means at their disposal to enable them to purchase fine physical apparatus.

We are sorry, however, that the work has not been revised and brought down to date. What we thought, from the title-page, to be a revised edition, is simply a reprint, verbatim, of the edition of 1861, and as the preface to that was dated 1856, the book represents the science of physics as it was 22 years ago. As this was before the discovery of spectrum-analysis, we find no mention of the spectroscope whatever in its pages. Nor are there any of the beautiful experiments of Helmholtz and König in acoustics. Nor do we find a word concerning the Holtz electrical machine, or similar modern forms of apparatus. We feel certain that no course of experimental lectures on physics, at the present day, leaves these important topics untouched. S.

Franklin Institute.

HALL OF THE INSTITUTE, Sept. 18th, 1878.

The stated meeting was called to order at 8 o'clock P. M., the Vice-President, J. E. Mitchell, in the chair.

There were present 145 members and 58 visitors.

The minutes of the last meeting (June 19th) were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting the following donations were made to the Library:

Illustrated catalogue of well excavators and prospecting machinery. From C. D. Pierce.

Transactions and Proceedings of the New Zealand Institute, vol. 10. 1877. By Jas. Hector. From the Institute.

Pennsylvania Archives. Second series. Vol. 7. Harrisburg, 1878. From J. Blair Linn.

Year Book of Education for 1878. From E. Steiger, New York.

Southall, J. C. Address on Man's Age in the World. From Board of Visitors of University of Virginia.

Specifications and drawings of patents issued from the United States Patent Office, for February, 1878. Washington. From the Patent Office.

Register of the Commissioned, Warrant and Volunteer Officers of the Navy of the United States, etc., to July 1st, 1878. Washington. From Secretary of the Navy.

Simmonds, P. L. Waste products and undeveloped substances. From S. Needles.

Map of British Columbia, showing coal-fields, etc., to illustrate report of Mr. J. Richardson, of the Geological Survey of Canada. 1876–7. From the Survey Office.

Report of the Superintendent of the United States Coast Survey, for 1875. Washington, 1878. From the Survey.

Annals of the Astronomical Observatory of Harvard College. Vol. 4, Part 2, and Vol. 9. From the College.

The Secretary's report embraced Tonkins' revolving Gauge-cock for steam boilers: Heston's Rubber cone packing, and the United States Metallic Packing Co.'s Packing for piston-rods, valve-rods, etc.; also the following apparatus and processes for producing multiple copies of writings, drawings, etc:

The Papyrograph; Edison's Electric Pen; Imlay's Mechanical Pen, and Bonwill's Perforating Pen.

Dr. Bonwill also read a short statement of the many purposes to which his apparatus can be applied, particularly in surgery and dentistry.

Profs. Houston and Thomson described and operated their new form of Electric Lamp,[1] intended to utilize, in producing light, the secondary current generated upon breaking the electric circuit.

The following letter was read:

PHILADELPHIA, *Sept. 18th*, 1878.

J. B. KNIGHT, ESQ., Sec. of the Franklin Institute:

Dear Sir:—Mrs. B. H. Moore desires you to announce to the Franklin Institute, at its next meeting, that she tenders to the Institute the sum of $10,000, to be placed in a trust hereafter to be created by her, and to be called the "Bloomfield Moore Memorial Fund," in remembrance of the late MR. B. H. MOORE; the annual income of said fund to be applied to the purchase of books for the Library, and the proper binding and keeping of said books.

C. B. MOORE.

On motion of Mr. H. Cartwright, seconded by Mr. C. S. Close, it was unanimously

Resolved, That the Franklin Institute accept with thanks the donation as proposed by Mrs. B. H. Moore.

Resolved, That the Institute return a grateful acknowledgment of the personal services rendered by Mr. Moore, and with pleasure will become the recipient of this Memorial Fund, which, they have no doubt, will inure to the benefit of the present as well as of future generations.

On motion, the meeting adjourned.

J. B. KNIGHT, *Secretary*.

---

[1] See page 252, this No.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

Vol. CVI. NOVEMBER, 1878. No. 5.

The Franklin Institute is not responsible, as a body, for the statements and opinions advanced by contributors to the Journal.

NEW DETERMINATIONS OF THE COEFFICIENTS OF FRICTION OF LUBRICATED JOURNALS, AND ON THE LAWS GOVERNING SUCH FRICTION.[1]

By R. H. Thurston, A. M., C. E.,
Professor of Mechanical Engineering at the Stevens Institute of Technology.

The writer became convinced, many years ago, that the generally accepted values of the coefficient of friction for lubricated surfaces were not applicable to such heavy machinery as he had been called upon, in the course of professional work, to design, to construct, and to operate. Experience frequently seemed to indicate, also, a wide departure, in such cases, from the accepted "laws of friction."

In the year 1869, or earlier, he invented an apparatus to re-determine these laws and these coefficients for a wide range of temperatures, pressures and velocities. The construction of the machine was delayed, however, some time, and no experiments were made for several years, when, finally, the construction of the apparatus was commenced in the workshops of the Stevens Institute of Technology, and experiments were begun in the Mechanical Laboratory organized by the writer in connection with the Department of Engineering.

---

[1] A paper read at the October meeting of the Am. Inst. Mining Engineers.

These machines have now been in use about five years, and have furnished an immense amount of valuable information. Those now in use are of two styles: one designed and built by the Class of 1877, Figs. 1 and 2; the other a much larger machine, Figs. 3 and 4. The first has been already frequently described,[i] and a working drawing of the second has been also published.[ii] For convenience, engravings of both are herewith reproduced.

Fig. 1.

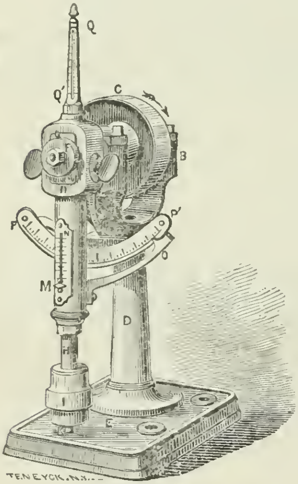
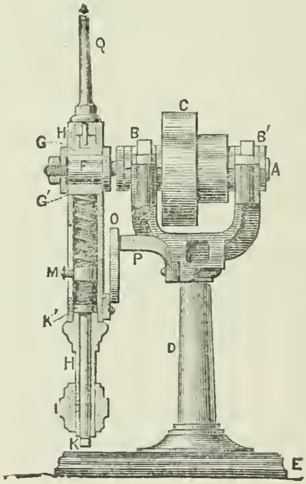


Fig. 2.



In the "'77 machine," a journal, *F*, is made on the overhung extremity of a shaft carried in the two bearings, *B B′*. This journal is grasped by brass boxes which are carried in a pendulum, *H H*. They are forced against the journal by a screw which compresses a coiled spring with a pressure which is read off on the scale, *N M*. A weight at the lower end of the arm, at *I*, gives it the necessary resistance to deflection. The angle of deflection is measured on the arc, *P P′*, in pounds of frictional resistance at the surface of the journal, *i. e.*, in such units that the division of the figures indicated by the pointer, at any given angle of deflection, by the figure indicated by the other pointer on *N M*, which indicates the total pressure on the journal, gives the coefficient of friction. A thermometer, *Q*, gives the rise of temperature as the bearing warms up.

---

[i] In *Scientific American*, *R. R. Gazette*, Jour. Frank. Inst., "Johnson's Cyclopedia," "Knight's Mechanical Dictionary," etc.

[ii] *R. R. Gazette*, Jan. 18th, 1878, p. 25.

The machine is fitted for a wide range of pressures, as is seen on the index-plate, *M N*, on the pendulum, *H H*, where the large figures represent the total pressures on the journal, and those opposite the corresponding pressure per square inch.

The speed of the machine, when the belt is upon the largest pulley of the cone, *C*, should be that which will give the least speed of rubbing at the surface of the testing journal, which is to be usually adopted.

The figures on arc, *P P′*, traversed by the pointer, *O*, attached to the pendulum, are such that the quotient of the reading on the arc, *P P′*, by the total pressure read from the front of the pendulum at *M N*, gives the "coefficient of friction," *i. e.*., the proportion of that pressure which measures the resistance due to friction.

A printed table is furnished with each machine, giving these coefficients for a wide range of pressures and arc-readings.

To determine the lubricating quality, we remove the pendulum, *H H*, from testing journal, *G G′*, adjust the machine to run at the desired pressure, by turning the screw-head, *K*, projecting from the lower end of the pendulum, until the index, *M*, above, shows the right pressure, and adjust it to run at the required speed by placing the belt on the right pulley, *C*.

We then throw out the bearings by means of the two little cams on the head of the pendulum, *H*, in the small machine, or by setting down the brass nut immediately under the head in the large machine; we next carefully slide the pendulum upon the testing journal, *G G′*, and see that no scratching of journal or brasses takes place.

Then we oil the journal through the oil-cups or the oil holes, set the machine in motion, running it a moment until the oil is well distributed over the journal.

Next stop the machine; loosen the nut or the cams which confine the spring, and, when it is fairly in contact and bearing on the lower brass with full pressure, turn the brass nut or the cams fairly out of contact, so that the spring may not be jammed by their shaking back while working. Now, start the machine again, and run until the behavior of the oil is determined, keeping up a free feed throughout the experiment.

At intervals of one or more minutes, as may prove most satisfactory, observe and record the temperature given by the thermometer, Q Q', and the reading indicated on the arc, P', of the machine, by the pointer, O. When both readings have ceased to vary, the experiment may be terminated.

Remove the pendulum, first relieving the pressure of the spring, and clean the journal and brasses with exceedingly great care from every sign of grease; and be especially careful not to have a particle of lint on either surface, or any grease in the oil-cup or oil-passages.

A comparison of the results thus obtained with several oils will show their relative values as reducers of friction.

In each case we record in tables like the blanks, which are sent with the machine:

1. The pressure and speed of rubbing at each trial.
2. The observed temperature.
3. The readings on the arc of the machine, *i. e.*, the frictional resistance in pounds.
4. The calculated coefficients of friction.

We enter at the end of the trial the average and the minimum coefficients, and the total distance *rubbed over* by the bearing surfaces.

To determine the liability of the oil to gum, we allow the machine to stand with the journal wet with oil, but with none feeding through the bearing, for 12 or 24 hours or more, as may be found necessary. Then start up and run a few moments until the reading on the arc, P P', having fallen to a minimum, begins to rise again; then stop *at once*. Compare the minimum coefficients thus obtained from the several oils to be examined; that which gives the smallest figure will be least liable to gum during the period of time given to the test.

To determine durability, we proceed as in determining the friction, excepting that the lubricant should not be continuously supplied, but should be fed to the bearing, a small and definite portion at a time—say a drop for each two inches length of journal. Extreme care should be taken that each portion actually reaches the journal and is not lost, either in the oil-hole or by being wiped off the journal, and that the portions applied are *exactly* equal.

When the friction, as shown by the pointer, *O*, has passed a minimum and begins to rise, the machine should be carefully watched, and should be stopped either at the *instant* that the friction has reached double the minimum, or when the thermometer indicates 212° F.; or else another portion of the lubricant should be then applied to the journal.

This operation should be repeated until the duration of each trial becomes nearly the same; an average may then be taken either of the time, of the number of revolutions, or of the distance rubbed over by the bearing, which average will measure the durability of that lubricant.

Next, we carefully clean the testing-journal and proceed as before with the next oil to be tested.

In making comparisons we always test the standard, as well as the competing oils, on the same journal, and under *precisely* the same conditions.

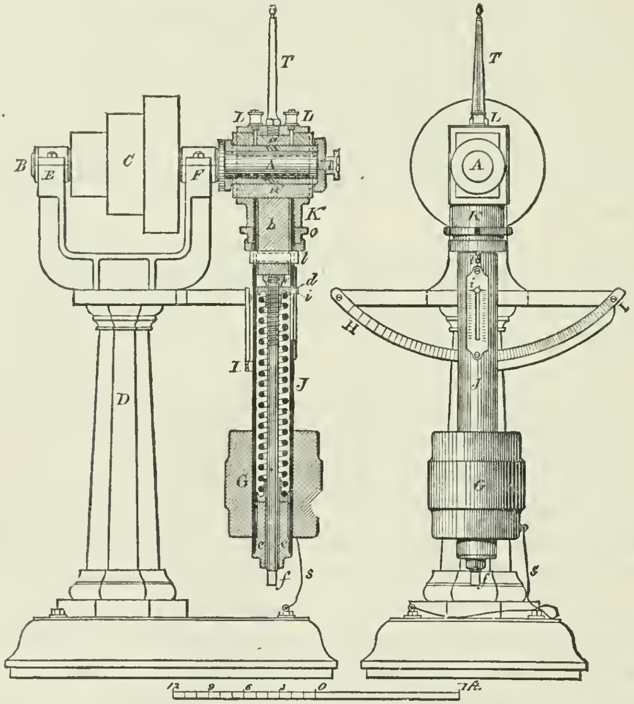
An approximate value, by which to compare the oils, can be calculated, based on the assumption that they will have a money-value proportionate to their durability and to the *inverse* ratio of the value of the coefficient of friction.

The larger machine is built to a scale about three times as great as that of the smaller, just described, and has a journal of standard car-axle size, 3¼ inches diameter and 7 inches long.

The speed is intended to be adjusted to speeds varying from that of a 26-inch engine-truck wheel at 60 miles an hour, down to that of a 42-inch wheel running 15 miles an hour. The pressures are adjustable from a few pounds total pressure up to 400 pounds per square inch, or a load of nearly 10,000 pounds on the journal.

Fig. 3 is a side elevation of the larger machine, with the journal and pendulum in section; and Fig. 4, a front elevation. It consists of a shaft, *A B*, which is driven by a cone pulley, *C*, the whole mounted on a cast-iron stand, *D*, terminating in a forked end at the top, with two bearings, *E* and *F*, in which the shaft runs. The shaft projects beyond the journal, *F;* and the projecting part, *A*, is provided with a sleeve or bushing, *m m*, the outside of which forms a journal on which the tests of oil are made. A pendulum, *A G*, is suspended from this journal with suitable bearings, *a a*, which work on the journal, *m m*. A heavy weight, *G*, is attached to the lower end of the pendulum. It is evident that the friction on the journal, *m m*, will have a tendency to move the pendulum in the direction of the revolution of the shaft and that the greater the friction on the journal the farther will the pendulum swing. A scale or dial, *H I*, is attached to the stand, and the distance the pendulum swings may be read off on this scale, which thus indicates the coefficient of friction of the lubricant on the journal. In order to get any desired pressure of the bearings on the journal, the pendulum is constructed as follows: A wrought-iron pipe, *J*, which is represented in Fig. 3 by

FIG. 3. FIG. 4.



solid black shading, is screwed into the head, *K*, which embraces the journal and holds the bearings, *a a*, in their place. In this pipe a loose piece, *b*, is fitted, which bears against the under journal-bearing, *a′*. Into the lower end of the pipe a piece, *c c*, is screwed with a hole drilled in the centre through which a rod, *f*, passes, the upper end of which is screwed into a cap, *d*. Between this cap and the lower piece, *c c*, a spiral spring, shown in section in Fig. 3 is placed.

The upper end of the rod has a cap, *e*, in which it turns, and which bears against the piece, *b*, which in turn bears against the bearing *a′*.

If the rod is turned with a wrench applied to the square head at *f*, it is obvious that the cap, *d*, will be either drawn down on the spiral spring, which will thus be compressed, or it will be moved upward, and the spring will thus be released, according to the direction in which the rod is turned. If the spring is compressed, its lower end will bear against the under cap and on the piece, *c c*, by which the pressure will be transmitted to the pipe, *J*, and thence to the head, *K*, and from that on the upper journal-bearing, *a;* while at the same time the upper end of the spring bears against the cap, *d*, which, being screwed on the rod, *f*, transmits its pressure upward to the cap, *e*, and from that to the loose piece, *b*, and from that to the under journal-bearing, *a′*. It will thus be seen that any desired pressure, within the limits of the elasticity of the spiral spring, may be brought upon the journal and bearings by turning the rod, *f*. The piece, *b*, has a key, *l*, which passes through it and the pipe, *J*. This key bears against a nut, *o*, which is screwed on the pipe, its object being to provide a ready means of relieving the journal of pressure by simply turning the nut, *o*, when it is desired to do so. An index, *i*, is attached to the spiral spring, so as to show the position of the latter. The oil is fed to the journal by means of oil-cups, *L L*, on top of the head, *K*, and a thermometer, *t*, is attached between the two cups, and from it the rise in temperature is observed. A strap, *s*, is attached to the pendulum, to prevent it from being thrown beyond the limits provided for it.

The earliest determinations published, were given in the *Polytechnic Review*, March 3d, 1877. Later results were given in a lecture before the Master Car-Builders' Association, in New York, Dec. 20th, 1877[i]; and still later figures were given the Am. Railroad Master Mechanics' Association, at their annual convention held at Richmond, in the spring of 1878.[ii]

In the course of this long series of experiments, extending over several years, and including work on all standard lubricating materials, and under pressures varying from 0 to 1000 pounds per square inch, at speeds of rubbing reaching 1200 feet per minute, and at all attainable temperatures, as well as with a great variety of material in journals and bearings, it was found that instead of being nearly constant in value, for even free lubrication, as assumed by engineers and physicists generally, the coefficient is variable in a marked degree by every change of pressure and of temperature ; that it is affected by velocity-changes, and by the character of the metals of the journal and its bearings. A new journal also gives a coefficient which usually decreases, first rapidly, then more and more slowly, as it wears, while heating, and especially " cutting," causing an immediate and great increase of friction.

---

[i] *Railroad Gazette*, Jan. 18th, 1878, p. 23.

[ii] *Railroad Gazette*, Aug. 2d, 1878, p. 384.

Friction with Varying Pressures.—An attempt was finally made to systematically determine the laws governing these variations of frictional resistance. A smooth journal, running in well-worn bearings, was lubricated with pure sperm oil, and the coefficients determined for a wide range of temperature, pressure and speed of rubbing.

The following table contains data secured during one part of this investigation.

Studying table A, we see that the coefficient rapidly diminishes with increase of pressure, until a pressure of over 500 pounds per square inch is attained ; the coefficient, after passing a pressure of probably 600 to 800 pounds per square inch, increases, and, at 1000 pounds, becomes about equal to that obtained at 100 pounds. It will be remembered that 500 or 600 pounds pressure is usually considered to be a limit not to be exceeded in general practice in machine construction and operation.

Nevertheless, it is not uncommon to find as high pressures as 1000, or even 1200, pounds in the crank-pins of steam-engines. In such cases, however, the pins are almost invariably of steel, and the journals of good bronze—conditions which are less seldom met with elsewhere. There is also, in this case, as wherever a "reciprocating force" acts to move a piece, a condition which permits higher pressures to be successfully worked than can be reached elsewhere ; the alternate application and relief of pressure, occurring between journal and bearing at each change of direction of the driving force, causes a release at such times, which permits the oil to find its way between the rubbing surfaces, and its expulsion is not then fully effected before the succeeding relief of pressure again permits its renewal. A somewhat similar action is consequent upon the rise and fall of a locomotive, or of a railroad car, in its springs, as it rapidly traverses even a smooth track.

TABLE A.—COEFFICIENTS OF FRICTION OF MOTION AND OF REST.—THURSTON.

(*a*) CAST IRON JOURNAL AND STEEL BEARINGS.

PRESSURES PER SQUARE INCH.	WINTER BLEACHED SPERM OIL.			WEST VIRGINIA OIL (MINERAL).			LARD OIL.				
	At 150 ft. per minute.	At Starting.	At Stopping.	At 150 ft. per minute.	At Starting.	At Stopping.	At 150 ft per minute.	At Starting.	At Stopping.		
Pounds.	*f*.	*f'*.	*f''*.	*f*.	*f'*	*f''*.	*f*.	*f'*.	*f''*.		
50	·013	.070	·030	·0213	·110	·025	·0200	·070	·010	Temperature in all cases, less than 115° F.	
100	·008	·135	·025	·0150	·135	·025	·0137	·110	·022		
250	·005	·140	·040	·0090	·140	·026	·0085	·110	·016		
500	·004	·150	·030	·0052	·150	·018	·0052	·100	·016		
750	0043	·185	·030	·0050	·185	·014	·0066	·120	·020		
1000	·0090	·180	·030	·0100	·180	·017	·0125	·120	·019		
(*b*) STEEL JOURNAL AND BRASS BEARINGS.										Ratio of $\frac{b}{a}$.	
										SPERM.	LARD.
500	·0030						·004			·75	·80
1000	·0080						·009			·88	·90

Where, as in our testing-machine, under a flywheel-shaft, or in other machines, this relief cannot take place, the limit of pressure is earlier met.

Referring again to the last table, it is seen that between 100 and 750 pounds, the value of the coefficient may be obtained approximately by the expression,

$$f = \frac{a}{\sqrt{P}},$$

in which a is a constant quantity, and P is the pressure in pounds per square inch; for sperm oil, $a = 0{\cdot}100$; for the best crude heavy mineral oil, $a = 0{\cdot}150$; and for lard oil, $a = 0{\cdot}125$.[1]

It will be presently seen that the law is modified by temperature and speed.

The following data were given by trials of two excellent kinds of grease and of sperm oil compared with them as standard:

COEFFICIENTS OF FRICTION OF GREASES—THURSTON.

Steel Journal; Bronze Bearings; Velocity, 300 feet per minute.

LUBRICANT.	PRESSURES, POUNDS PER SQUARE INCH.					
	100	200	300	400	500	Average.
Sperm Oil, .	·0141	·0063	·0049	·0042	·0039	·0067
Grease, No. 1,	·0249	·0146	·0125	·0105	·0114	·0140
" No. 2,	·0188	·0198	·0160	·0146	·0175	·0173

Their relative average values, in reducing friction, stand, therefore: sperm, 100; No. 1, 44·8; No. 2, 37·7; which figures would also represent their relative money values, if estimated on that basis simply.

The method of variation with pressure, already noted, is here again illustrated, although the mathematical expression has a different set of constants, and the variation, at this speed, is more nearly as the inverse ratio of the cube root of the pressure.

---

[1] Some of these facts and deductions were published originally in a paper prepared in the spring of the year 1878, and read at the St. Louis meeting of the Am. Assoc. for Advancement of Science. This paper includes work done up to that time, supplemented by the more complete investigations since made. The research is still in progress, and determinations for other conditions will be published when obtained.

Friction of Quiescence.—In table A is presented a set of figures which are both new and important. In the columns headed "At 150 feet per minute," are given the coefficients of friction at the several pressures, as given when the rubbing surfaces are in motion at that relative velocity. These are the common and most usually required figures. We have given in the other columns, however, values which are seen at a glance to be immensely greater, and of which the values vary by an entirely different law. The first set, "At starting," are the well understood coefficients of friction of rest, varying with the pressure and with the nature of the unguent from 0·07 to 0·18. These values have, I think, never been determined before in this way, and possess great importance, not simply intrinsically, but also as throwing some light upon the effect of motion upon the efficacy of lubrication. It is seen that they increase with the pressure, instead of diminishing as do the coefficients of friction of motion; and that, at the highest pressures, their values become from ten to forty times the corresponding values of the latter. It is thus seen that, in the effort required to move heavy machinery, vastly greater force is demanded to overcome friction at the instant of starting, than after motion has once commenced. I presume that every experienced engineer or mechanic has known instances in which this difference has been so marked as to cause great difficulty in starting a machine which, once in motion, moved with comparative ease.

The method of variation of the coefficient for rest, is seen by reference to the table, to be such that their numerical values may be approximately estimated, for the cases here considered, by the formula,

$$f = 0{\cdot}a' \sqrt[3]{P},$$

in which $a' = 0{\cdot}02$ for sperm and heavy mineral oil, and $a' = 0{\cdot}015$ for lard oil.[1]

The figures in the columns headed "At stopping," were given while the machine was rapidly coming to a stop, after the driving belt had been shifted to the loose pulley. They are, as would be expected, intermediate in value between the other figures, and have, apparently, no practical importance. They may be taken as constant at all pressures.

---

[1] See paper, by the author, in Proceedings of Am. Assoc. for Advancement of Science, St. Louis meeting, 1878.

TABLE B.—COEFFICIENTS OF FRICTION.—THURSTON.

New Journal of Steel; Bearings of Bronze; Velocity, Pressure and Temperature, Variable; Lubricant, Standard Sperm Oil.

SPEED PER MINUTE.	30 FEET PER MINUTE.					100 FEET PER MINUTE.					250 FEET PER MINUTE.		500 FEET PER MINUTE.		1200 FEET PER MINUTE.		
Pressure per sq. inch. Pounds.	200	150	100	50	4	200	150	100	50	4	200	100	200	100	200	150	100
Temp. Fahr.																	
175°	....	....	....	....	....	....	....	....	....	....	....	....	....	....	·0050	....	....
170	....	....	....	....	....	....	....	....	....	....	....	....	....	....	·0053	·0050	·0061
165	....	....	....	·0200	·125	....	....	....	....	....	....	....	....	....	0056	·0050	·0061
160	....	....	....	·0175	·125	·0280	....	·0025	·0037	....	....	....	....	....	·0056	·0053	·0061
155	....	....	....	·0137	·125	0190	·0110	·0025	·0037	....	....	....	....	·0037	·0056	·0058	·0061
150	·0500	·0500	·0250	·0125	·125	·0140	·0074	·0025	·0037	·0630	0047	·0028	0053	·0037	·0060	·0058	0061
145	....	....	....	·0112	·125	·0110	·0058	·0025	·0037	·0630	....	....	....	....	·0060	·0058	·0070
140	·0250	·0330	·0110	·0087	·125	·0100	·0050	·0025	·0037	·0630	·0047	·0030	·0053	·0037	·0062	·0058	·0070
130	·0160	·0200	·0044	·0075	·125	·0087	·0041	·0019	·0037	·0630	·0047	·0030	·0053	·0037	·0065	·0062	·0075
120	·0110	·0110	·0044	·0075	·125	·0056	·0035	·0019	·0037	·0630	·0047	·0037	·0056	·0037	·0069	·0067	·0080
115	....	....	....	....	....	....	....	... .	....	....	·0048	....	·0060	·0014	....	.. ..	....
110	·0100	·0033	·0037	·0062	·094	·0044	·0033	·0019	·0037	·0630	·0050	·0044	·0062	·0050	·0075	·0075	·0087
100	·0075	·0028	·0031	·0056	·094	·0040	·0033	·0019	·0037	·0630	·0056	·0045	·0065	·0061	·0081	·0083	·0094
95	·0060	·0025	·0031	·0050	·094	·0040	·0033	·0019	·0037	·0630	·0062	·0050	·0072	·0061	0087	·0092	0125
90	·0056	·0025	·0031	·0037	·094	·0040	·0033	·0019	·0037	·0630	·0070	·0052	·0075	·0061	·0100	·0170	·0150

Friction with Varying Velocity—Thurston.—Refering to the accompanying Table B, in which the effects of varying velocities, as well as of coincident variation of pressure and of temperature, are exhibited, as given by experiment in the Mechanical Laboratory of the Stevens' Institute of Technology, it is readily seen that the change in value of the coefficient of friction with change of velocity is not great for machinery in which that velocity remains within usual limits, and at the usual temperature of a cool and properly working journal. The effect of change of velocity varies, as is here shown, with change of temperature and of pressure.

For cool journals in good condition, lubricated with good sperm oil, and between the limits of 100 and 1200 feet per minute, these values may be taken as varying approximately as the fifth root of the speed of rubbing, *i. e.*,

$$f = a\sqrt[5]{V}.$$

At a constant pressure of, say, 200 pounds, we may call $a = 0\ 0015$.

Friction with Pressure and Velocity Varying Simultaneously.—We may now readily construct an equation which shall give values of the coefficient of friction for good journals lubricated with sperm oil, and for all ordinary variations both of pressure and velocity, since $f \propto \sqrt[5]{V}$, and $f \propto \sqrt[\frac{1}{2}]{P}$, we have approximately,

$$f = a\frac{\sqrt[5]{V}}{\sqrt[2]{P}},$$

in which we may take $a = 0{\cdot}02$ to $0{\cdot}03$ for general use.[1]

The value of a for other conditions, and with other materials, may be determined by a comparison, by means of the testing-machine, of those materials under the assumed conditions, with those obtained with the standard oil under standard conditions, as here given.

Friction with Varying Pressures, Speeds and Temperatures.—We have here some exceedingly interesting data. The following were obtained by heating the bearing by its own friction to a maximum, 170° Fahr., well within that liable to produce alterations of the oil, and noting the temperatures while cooling. It should be remembered that no temperature-reading can be taken as more than approximate.

---

[1] *Vide* paper, by the author, "On Friction Measurement," etc., Proc. Am. Assoc. for Advancement of Science, 1878.

FRICTION AND TEMPERATURE—THURSTON.

Steel Journal; Bronze Bearings; Lubricant, Sperm Oil;
Velocity, 30 feet per minute.

PRESSURE PER SQUARE INCH.	TEMPERATURE, FAHR.	COEFFICIENT OF FRICTION. *f*.	PRESSURE PER SQUARE INCH.	TEMPERATURE, FAHR.	COEFFICIENT OF FRICTION. *f*.
200	150	0·0500	150	110	0·0035
200	140	0·0250	100	110	0·0025
200	130	0·0160	50	110	0·0035
200	120	0·0110	4	110	0·0500
200	110	0·0100			
200	100	0·0075	200	90	0·0040
200	95	0·0060	150	90	0·0025
200	90	0·0056	100	90	0·0025
			50	90	0·0035
			4	90	0·0400

The figures just given would indicate that the sperm oil used in this instance, and under these conditions including that of exceptionally low speed, works best at lowest temperatures, and that a heating journal gives rapidly increasing friction and rapidly increasing danger. At usual temperatures, 90° to 110° Fahr., the best pressure seems to have been from 100 to 150 pounds on the square inch.

It would, however, be wrong to predicate general conclusions on such limited data, and the study of Table B is exceedingly interesting and instructive.

There are there given coefficients of friction for temperatures from 90° to 150° F., for pressures up to 200 pounds per square inch, and for velocities of rubbing up to 1200 feet per minute. This table is, in fact, a compendium of data for all ordinary conditions of the working of light and of moderately heavy machinery.

We find there some exceedingly valuable and very curious facts, bearing directly on our our everyday work.

We have seen that at the low speed of thirty feet per minute, the coefficient increases rapidly with increase of temperature, and that at 200 pounds pressure an increase of 50° F. may increase its value to nearly ten times the minimum, the rate of increase rapidly rising as pressures are greater.

We now find, at speeds of 100 feet per minute, that the friction does not vary between 90° and 150° F. at pressures below 50 pounds per square inch, but that it rises nearly 300 per cent. at a pressure of 200 pounds, over 100 per cent. at 150 pounds, and 33 per cent. at 100 pounds.

At speeds exceeding 100 feet per minute, heating the journal within this range of temperature *decreases* the resistance due to friction, rapidly at first, then slowly and gradually a temperature is approached at which increase takes place and progresses at a rapidly accelerating rate. It is seen that this change of law takes place at a temperature of 120° F. and upward, at all higher speeds the decrease continues until temperatures are attained exceeding those usually permitted in machinery, and very commonly not far from 150° F., and sometimes up to 180 F., or probably even higher. I have found the decrease, at 1200 feet per minute, to continue up to 175° F., at which the value at 200 pounds pressure was, in the cases determined, 0·0050. The limit of decrease is reached, under 100 pounds pressure, at 150° F. when running at this high speed.

At 200 pounds pressure, the *temperature of minimum friction*, for conditions here illustrated, seems to be, in Fahrenheit degrees, about

$$t = 15 \sqrt[3]{V}.$$

On either side this point on the thermometric scale, it may be assumed, for a narrow range, to vary, as the temperature departs from that point, directly or inversely, as the case may be, as the temperature. The fact is, however, that this coefficient of minimum friction is found, usually, over quite a wide range of temperature.

Again, studying in this most instructive of our tables the method of variation with pressure at higher temperatures, we find the effect of change of pressure to be much more marked at the higher temperatures with low speeds; and, singularly enough, as when studying the effect of variation of friction with change of temperature at a standard pressure as affected by the variation of speed, we here find a change of law for the higher speeds.

At a velocity of 1200 feet per minute, the coefficient remains practically uniform with varying pressure at 150° Fahr.; while below that temperature, the friction-coefficient diminishes with increasing pressure. At velocities of rubbing of 250 to 500 feet per minute, the temperature of the constant coefficient is about 100°; at 100 feet this peculiar condition is seen at about 120°, when extreme pressures (4 pounds and 200) are compared, but the value is seen to be a little over one-half as much at 50 and 150 pounds, and to become a minimum—0·0019—at 100 pounds pressure, a similar behavior is noted at the lowest speed observed—30 feet—at about 125° F., and the same fall to a minimum at the intermediate pressure.

It would seem that, at all times, there is a tendency to acceleration of outflow from the journal, with increasing fluidity due to increasing temperature, which tends to cause an increase of friction; while the effort of capillarity to resist this outflow, seems effectively aided by increasing the velocity of rubbing.

A *balance* between these opposite influences is seen to take place at the slowest speed, when the pressure is somewhere below 4 pounds per square inch; this occurs at a speed of 100 feet per minute, at a pressure of 50 pounds; at 250 feet when the pressure becomes about 150 pounds; probably, it happens at the speed of 500, at somewhere about the same point, and at 1200 feet per minute the benefit of increased speed is sufficient to produce this balance when the pressure exceeds 200 pounds per square inch.

These data would seem to give very useful information relating to the method of action of lubricating materials.

Finally, it has now become evident that such a series of comparisons as I have here made, are needed in every case in which the real value and the extent and the conditions of application of any single oil, or other unguent, are to be learned. Such a systematic examination reveals precisely the conditions which the lubricant best meets, and tells, with a certainty, at what pressure and at what speed it does its best work.

Conversely, the speed, the pressure and other conditions of working being known, a reference to a set of such determinations for various lubricants being made, it is easy to ascertain at once which is best adapted to the work in view.

Thus, having had occasion to determine the value of the friction-coefficients of a material having a very high reputation as a "cylinder oil"—*i. e.*, an oil for use in the cylinders of steam-engines,—it was found that its distinguishing peculiarity, as compared with oils not specially adapted for such purpose, was a continually diminishing coefficient, quite up to the limit of temperature of locomotive steam-pressure.

Any new lubricant should always have its true value and best adaptations thus determined. I have presented the figures for a fine steel journal, running in good bronze bearings and lubricated with sperm oil, not simply as an illustration, but principally as representative of the best set of conditions for use as a *standard* in making comparisons of other unguents of less value, or less known, or under less favorable conditions.

CONCLUSIONS.

Studying the facts here laid out, and the data acquired by many hundreds of other experiments made on one or the other of these last described machines for testing lubricants, we may now recapitulate facts and figures for ordinary use in machine-design and in estimating losses of power by friction.

1. The great cause of variation with well-cared-for journals is alteration of pressure, and it is seen that the higher pressures, within the range of these experiments, give the lowest percentages of loss of power by friction.

2. The value of the coefficient is greatly modified by the state of the rubbing surfaces; and the necessity of keeping journals in perfect order cannot be too strongly insisted upon. A single scratch has its effect in wasting power. A journal should have its surface as smooth and as absolutely uniform as a mirror. Every well-kept journal has such a surface.

3. For general purposes, the value of the coefficient may be obtained pretty closely by dividing 0·08 to 0·10 by the square-root of the pressure in pounds per square inch,—*i. e.*, $f = \frac{0{\cdot}10}{\sqrt{p}}$ —in which case it is given as that fraction of the total pressure which measures the resistance due to friction.

4. The coefficient for rest or starting may similarly be taken as about 0·02 the cube-root of the pressure—*i. e.*, $f' = 0{\cdot}02 \sqrt[3]{p}$ —for sperm and for crude mineral oil of good body, and 0·015 the cube-root—*i. e.*, $f' = 0{\cdot}015 \sqrt[3]{p}$ —for lard oil. For closer estimates, the tables just given can be referred to directly. It would seem that each material has its own coefficient and its own appropriate exponent in the expression, $f = c\,P^x$.

5. The coefficient for the instant of coming to rest, under conditions such as are here given, is nearly constant and may be taken at 0·03.

6. The resistance due to friction varies with velocity, decreasing with increasing velocity, rapidly at very low speeds, as from 1 to 10 feet per second,[1] and slowly as higher speeds are reached, until the law changes, and increase, at ordinary temperatures, takes place and at a very low rate throughout the whole range of usual velocities of rubbing in machinery.

The value may be taken for use in machine-design and mill-work, and at a pressure of 200 pounds per inch, as $f = 0{\cdot}0015 \sqrt[5]{V}$.

7. With pressure and velocity varying we may take, roughly,

$$f = 0{\cdot}02 \frac{\sqrt[5]{V}}{\sqrt[2]{P}}, \text{ to } f = 0{\cdot}03 \frac{\sqrt[5]{V}}{\sqrt[2]{P}}.$$

8. That the effect of heating journals under conditions here illustrated is to *increase* the friction in proportion to the square of the increase of temperature above, say, 90° or 100° F., at a speed as low as 30 to 100 feet per minute, while at higher speeds the opposite effect is produced and the coefficient *decreases* more nearly as the square-root of the rise of temperature.

Under all conditions commonly met with by the maker of machines, the latter is the method of change.

9. The temperature of minimum friction, under the conditions of these experiments, is about $t = 15 \sqrt[3]{V}$ for a pressure of about 200 pounds per square inch.

10. The endurance of any lubricant should be determined by actually wearing it out upon a good journal under the pressures and velocities proposed for its use.

The economy with which it can be used will also be dependent upon its natural method and rate of flow, and upon its capillary qualities, as well as upon its intrinsic wearing-power, and the method adopted in feeding it. Greases, therefore, are usually more economical than oil, *even if having a less wearing capacity.*

---

[1] We deduce this conclusion from the experiments of Professors Jenkin, Ewing and Kimball, at speeds below any given in this paper.

11. The only method of learning the true value of a lubricant and its applicability in the arts, is to place it under test, determining its friction-reducing power and its other valuable qualities, not only at a standard pressure and velocity and at ordinary temperatures, but measuring its friction and endurance as affected by changing temperature, speeds and pressures throughout the whole range of usual practice.

12. The true value of an oil to the consumer is not proportional simply to its friction-reducing power and endurance under the conditions of his work; but its value to him is measured by the difference in value of power expended, using different lubricants, less the difference in total cost of oil or grease used; but, for commercial purposes, no better method of grading prices seems practicable than that which makes their market-value proportional to their endurance divided by their coefficients of friction.

The consumer will usually find it economical to use that lubricant which is shown to be the best for his special case, without respect to price, and will often find the real economy in using the better material, sufficient to repay the excess in total cost very many times over. He cannot afford to accept low grade unguents, even without charge.

13. To secure maximum economy, the journal should be subjected to a pressure determinable by either Rankine's or Thurston's formula; the most efficient materials should be chosen for the rubbing surfaces; they should be reduced to the most perfect state of smoothness and perfection in form and fit; a lubricant should be chosen which is best adapted for use under the precise conditions assumed; the lubricant should be applied precisely as needed, and by a method perfectly adapted to the special unguent chosen.

The semi-fluid lubricants, if equally good reducers of friction, are usually most economical, in consequence of their peculiar self-regulating flow, as the rubbing parts warm or cool while working.

Where heating is not to be anticipated, maximum economy is obtained by the minimum rate of supply allowable only if that supply be maintained with absolute uniformity.

STEVENS' INSTITUTE OF TECHNOLOGY,
Hoboken, N. J., Sept., 1878.

ON THE DRIVING POWER OF LEATHER BELTS.

By J. H. Cooper.

One of the earliest attempts at investigating the essential conditions of driving belts and of formulating a rule and table for ready reference, is that of M. Laborde, dating prior to the year 1833. As his memoir is little known and not easily accessible, a correct presentation of his views is desirable, and to this end the literal rendering of his paper, together with data from other authorities for comparison, is given below.

It is worthy of note that M. Laborde derived his data from belts in use, and that he relied for years upon the rule which he has given.

After adopting a formula, based upon the area of contact, as the right measure for the transmitting power of a belt, introducing dimensions dictated by his own successful practice for a dynamic unit, we find our author stating distinctly the limitations of his rule to 180° of pulley contact, and granting to each user of belts the privilege of substituting his own unit of measure, well knowing the prevalence of differing opinions on this feature of the subject, as we find existing at this time, but of the reliability of the formula he is sure.

All subsequent writers on belting have reproduced Laborde's "well-known truths" in some form or other, which may be proven by reference to the ample quotations given in the writer's "Treatise on the Use of Belting."

These truths are readily deducible from his text, and are here condensed:—

The resistance to be overcome must be less than the force required to slip the belt.

The tension must not injure the belt.

The tension must not strain the shafts nor unnecessarily increase journal friction.

The belt must adapt itself perfectly to the pulley surface.

The belt should be of single thickness.

The pulley surfaces must be smooth.

A belt under like conditions will slip the same on large as on small pulleys.

The efficiency of a belt is as the product of its width and speed.

The best driving by belts is derived from the higher speeds; for low speeds gearing should be used, and generally:—

The efficiency of belts is best obtained from high speed, low tension and reduced width.

And, as for the rule, it will be necessary first to get exact dimensions of the belt he has chosen for the "starting point," in English measure, before comparison can be made.

The belt selected by M. Laborde which readily transmitted one French horse-power under safe tension, on smooth-faced pulleys of equal diameter, had a breadth of 3 *pouces* and 500 feet of speed per minute; but not having the means at hand of converting this unit of measure into English, I have taken Armengaud's figures of the same belt, which are 0·081 m. (= 3·189 inches) for the breadth and 162·50 m. (= 533 feet) for the speed, transmitting one *cheval* of 75 kilogrammetres (= ·986 English horse-power).

In other words, this belt had a surface velocity of 143·656 square feet per minute per horse-power and worked under a stress of 19·15 pounds per inch of width.

This tension is low compared with American practice, but other foreign writers have adopted near the same base as that of Laborde.

From "Tables, Rules and Data, by D. K. Clarke," London, 1877, I quote: "M. Claudel instances the common experience that a belt 3¼ inches broad, moving at a velocity of 9 feet per second, can very well transmit one horse-power with ordinary tension, and without over-straining, working on turned and smooth pulleys of equal diameter; the working tension is only about 20 pounds per inch wide."

It will be noticed how nearly Claudel's example of working belt corresponds with that of Laborde; it is probably the same.

"Dr. Hartig found, from experiments made by him in a woolen mill, that the tension of the driving belts varied from 30 pounds to 532 pounds per square inch of section, and that it averaged 273 pounds per square inch."

"An average working strength of 300 pounds per square inch of section of leather belts may be accepted for purposes of calculation."

M. Carillon, M.E., of Paris, quoted by Armengaud, employs as base, "A belt can transmit one horse-power, if it have a surface velocity of 96·9 square feet per minute, providing not less than one-third of the circumference of either pulley be embraced." This is equivalent to a working stress of about 28 pounds per inch width of belt.

M. Morin I find variously quoted: 275, 284, 285 and 355 pounds per square inch of section for continuous working stress of belting leather, being attributed to him. Box gives 310, Haswell 350, Abel 320, and Webber adopts 330 for a purpose hereafter explained.

The thickness of belts is also differently stated; many writers name $\frac{3}{16} = \cdot 1875$ inch; Morin says, ·1575 to ·3150 inch; Webber, ·1666 inch, and Towne, $\frac{7}{32} = \cdot 219$ inch.

It is easy now to show the origin of different rules for the driving power of one inch width of belting, for if we take $350 \times \cdot 1875 = 65 \cdot 625$ pounds, we have the rule adopted by Briggs and Towne, and if we take $330 \times \cdot 1666 = 54 \cdot 978$ pounds, we have Webber's rule. Each starting from a different base, with different section of material.

In fact, a single leather belt in good driving condition will transmit 100 pounds to the inch of width, as shown in Art. 15, "Use of Belting."

We have, at this stage of the inquiry, at least reached the *extremes* of reliable practice—20 and 100 pounds driving-power to the inch width of single leather belting—it will not be difficult, then, to reconcile the differences of the *means*.

If, instead of taking Morin's highest figures for continuous working stress on belting leather, we approach a mean of the figures quoted, say 330 pounds—employing Webber's line of argument—we strike the component part of the horse-power unit, whence we reach the following convenient and reliable rules:—

330 pounds at 100 Fpm. = 33,000 pounds 1 Fpm.;

or 1 square inch of belting at 100 Fpm. = 1 horse-power.

If belting leather be $\frac{1}{6}$ inch thick, then,

1 inch width at 600 Fpm. = 1 horse-power; which proves that the old "rule of thumb" has foundation in fact.

Furthermore, $\frac{600}{12} = 50 =$ square feet of belt per minute per horse-power.

Also, we have $\frac{33000}{50 \times 12} = 55 =$ stress in pounds per inch of width.

And, finally, of rules it may be said the practical mechanic needs but one, for the ordinary cases of transmission of power by belting, and that one is a very simple statement:

It is the stress in pounds which each inch of width of belt will safely and continuously bear at any velocity.

From what is said above, the reader will clearly understand the practical range of belt capacity as given in the books. From Laborde's starting point of near 20 lbs., which is certainly safe, even with low quality of belting, to the greatest constant load, say 100 lbs., which a single leather belt will carry. Between these working limits, the choice of stress for belting will vary with the quality, section, length and condition of the belts employed, and with the proportion of pulleys and of speed in the system of mechanism of which they form a part.

RESEARCHES ON THE PRINCIPLE OF THE EMPLOYMENT OF BELTS FOR TRANSMITTING POWER.

By J. B. Laborde, M. E.[1]

The first idea which presents itself in this research is, that the resistance to be overcome must be less than the force which causes the belt to slip upon the circumference of the pulley. The second is, that the tension of a belt must not arrive at a point to stretch it, because it would be too quickly destroyed. The third is, that drawing too strongly upon the axes, the resistance increases, as if these axes were increased, in the same proportion in weight as is represented by the tension, which necessitates an increase in the strength of the journals.

Yet a fourth question presents itself: That a belt must be very flexible, or, to express it better, very supple, in order that the power employed to cause it continually to touch in all its parts, be as little as possible.

One can then conclude, with these four reflections, that a belt ought never to be doubled, but consist of a single thickness of leather, softened, when dry, with plain tallow; that it must never be employed at a tension which can stretch it to a point to deform it, and that it ought to adapt itself perfectly to the circumference of the pulleys; that for this reason, the pulleys must be turned smooth, and not ridged, neither lengthwise nor crosswise, as is often done.

These well-known truths have only helped us to find a rule which governs the breadth and the speed, according to the resistances to be overcome.

---

[1] Laborde's original paper was published in the Bulletin of the Industrial Society of Mulhouse, Alsace; a MS. copy of this was kindly furnished by Mr. V. Steinlen, and loaned to the writer by Mr. R. Briggs.

If we wish to transmit power, the necessary force of which be represented by 7, and the breadth of the belt be represented by a number, for example 10, and by a speed of 100, it is evident that to transmit a double force, a breadth of 20 with a speed of 100 will be necessary; or 10 of breadth with 200 of speed; or briefly, there is necessary a breadth and a speed, such that their product, comparative at first, be in the ratio of 2 to 1; hence we can conclude that the forces to be transmitted are to each other as the products of the breadths of the belts, multiplied by their speeds.

Then calling f' a known force taken for a base, l' a known breadth; v' a known speed, taken equally for a base. Calling, also, f'' any force whatever, l'' a breadth, and v'' a speed in the product, let it be relative to this force whatever, and we shall have the following proportion:

$$f' : f'' :: l' v' : l'' v'', \text{ or } f' l'' v'' = f'' l' v',$$

which will be the general formula.

It is then no longer the question to find, in practice, a base or starting point.

Here each practitioner can vary his opinions on the adoption of this base, but all must be in accordance with the formula.

My experience has shown me, as a good base, that the force of 6 men, or of a horse, or, to express it better, a dynamic unity, is transmitted very well with a breadth of 3 inches (*pouces*), and 500 feet of speed per minute. Such a belt acting upon a non-ridged pulley, *i. e.*, smoothly turned, has no need of a strong tension, and does not deform itself. It is well understood that this refers to a half-embraced pulley, for in transmissions where the pulleys are embraced but a fourth or a sixth, we must modify the rule, but the base is correct, whatever the diameter of the pulley may be; and, in fact, if the pulley be 5 feet in circumference, it will make 100 turns per minute, but if it be only $2\frac{1}{2}$ feet, it will make 200 turns; it will then, during the same time, have presented the same surface to the action of the belt; which explains why, when a large or a small pulley, each half-embraced by the belt, the belt does not slip sooner on one than on the other. (However, we must not descend to the infinitely small, for then the movements will be defective.)

According to the statements which my experiment has shown me as a good case, I have drawn up the following table, which has served me as a guide in my applications for the last ten years:

TABLE SHOWING THE BREADTHS OF BELTS ACCORDING TO THEIR SPEEDS AND THE MOTIVE FORCES WHICH ARE TO BE TRANSMITTED.

F′ = 1 horse-power.
L′ = 3″ breadth of belt. } Case.
V′ = 500 feet of speed.

FORMULA $F' L'' V'' = F'' L' V'$.

SPEEDS PER MINUTE EXPRESSED IN FEET.

Of the Table. { F″ = motive forces.
L″ = corresponding breadths.
V″ = different speeds.

PROPORTIONAL BREADTHS IN INCHES, LINES AND POINTS.

Forces to be transmitted.		3000		2500		2000		1600		1200		1000		800		650		500		400		325		275		225		175		140		100		75		50
Men.	Horses.	I.	L.	I.	L.P.	I.	L.P.	I.	L.P.	I.	L.P.	I.	L.	I.	L.	I.	L.	I.	L.	I.	L.	I.	L.	I.	L.	I.	L.	I.	L.	I.	L.	I.	L.	I.	L.	I.
1		0	1	0	1·2	0	1·5	0	1·9	0	2·5	0	3	0	4	0	5	0	6	0	7	0	9	0	11	1	1	1	5	1	9	2	6	3	4	5
2		0	2	0	2·4	0	3·	0	3 8	0	5·	0	6	0	7	0	9	1	0	1	2	1	6	1	10	2	3	2	10	3	6	5	0	6	8	10
3		0	3	0	3·6	0	4·5	0	5·7	0	7·5	0	9	0	11	1	2	1	6	1	9	2	3	2	9	3	4	4	3	5	7	7	6	10	0	15
4		0	4	0	4·8	0	6·	0	7·6	0	10·	1	0	1	3	1	6	2	0	2	4	3	0	3	8	4	5	5	8	7	0	10	0	13	4	20
5		0	5	0	6·	0	7·5	0	9·5	1	0·	1	3	1	7	1	11	2	6	2	11	3	9	4	7	5	6	7	1	8	9	12	0	16	8	25
6	1	0	6	0	7·2	0	9·	0	11·4	1	2	1	6	1	10	2	4	3	0	3	6	4	6	5	5	6	8	8	7	10	7	15	0	20	0	30
	2	1	0	1	2 4	1	6·	1	11·	2	4·	3	0	3	8	4	7	6	0	7	0	9	0	10	10	13	4	17	1	21	1	30	0	40	0	60
	3	1	6	1	9 6	2	3·	2	10·	3	6·	4	6	5	7	6	11	9	0	10	6	13	6	16	4	19	11	25	7	31	8	45	0	60	0	90
	4	2	0	2	4·8	3	0·	3	9·	4	8·	6	0	7	5	9	2	12	0	14	0	18	0	21	10	26	7	34	2	42	2	60	0	80	0	120
	5	2	6	3	0	3	9·	4	9·	6	0·	7	6	9	3	11	6	15	0	17	6	22	6	27	3	33	3	42	9	52	0	75	0	100	0	150
	6	3	0	3	7·	4	6·	5	8·	7	2·	9	0	11	1	13	10	18	0	21	0	27	0	32	8	39	11	51	4	63	4	90	0	120	0	180
	7	3	6	4	2·	5	3	6	8·	8	4·	10	6	13	0	16	1	21	0	24	6	31	6	38	2	46	3	59	10	73	10	105	0	140	0	210
	8	4	6	4		6	0	7	7·	9	6·	12	0	15	0	18	5	24	0	28	0	36	0	43	7	52	10	68	5	84	5	120	0	160	0	240
	9	4	6	5	4·	6	9·	8	7·	10	8·	13	6	16	8	20	8	27	0	31	6	40	6	50	0	59	6	76	11	95	0	135	0	180	0	270
	10	5	0	6	0·	7	6·	9	6·	11	10·	15	0	18	6	23	0	30	0	35	0	45	0	54	6	66	2	85	6	105	6	150	0	200	0	300

A C

B D

This table clearly represents at a glance as to how far one can make use of belts to transmit power, and at what point to abandon them for gearing; for all that is below the line *C D* would be a very bad use of belting. For cases which lie between the lines *A B* and *C D*, two belts running 3 or 4 inches apart should be used.

It would be absurd, also, to think of making belts of one, two, three, etc. lines in width, for in order that a belt draw upon the pulley, it must be at least 2 inches wide, only it is not stretched at all, for example, the belts of stampers: that of a cotton stamper, according to calculation, would be sufficiently wide at 4 lines to drive it, but it is necessary to make them 2 inches wide in order that the velocity does not cause them to run off pulleys without grooves.

It is well to remark that on account of their excess of breadth, so much less tension is given to them; it is not the same with the driving belt of this machine, whose speed is 400 feet per minute, and at that speed has to overcome one horse-power.

The corresponding breadth in the table is found to be 3 inches 6 lines, and there is here no reason to modify the rule.

It is to be noticed, at the two extreme angles of the table, that a belt of 5 inches at a speed of 3000 feet can transmit a force of 10 horse-power, while the same belt at a speed of 50 feet can transmit only the power of one man.

ASTRONOMICAL FORECASTS.

By Pliny Earle Chase, LL.D., Professor of Philosophy in Haverford College.

Successful prediction furnishes the best possible test for any hypothesis. It is daily illustrated in the *experimentum crucis* of the chemist and physicist; astronomy has furnished two well-known instances, in the discovery of the asteroidal belt, and in the discovery of Neptune.

In the last number of this Journal,[1] I announced a second verification, which was also a sixth confirmation, both of a hypothesis and of an astronomical prediction which I published in 1873. In the present paper I propose to give a complete series of such verifications and confirmations, together with a brief statement of the principles on which they are based. By a "confirmation," I mean any fact, whether previously known or not, which accords with a hypothesis; by a "verification," I mean a confirmation which was not known until after the hypothesis or prediction was published.

---

[1] See p. 286.

That the planets of the solar system, and the light-shedding orbs of stellar systems, are arranged in some kind of order, was known even before Job heard the voice which told of the time "when the morning stars sang together." In some foregoing articles,[1] on "The Music of the Spheres," "Planetary Mechanics," and "Music of the Moons," I set forth some of the most satisfactory cosmical groupings that have been discovered, and showed that those which were based upon laws of musical rhythm, or harmonical progression, showed the closest accordance with actual positions. Even as a bare matter of fact, this was interesting; if the fact can be traced to some general law, the interest must be largely increased.

When vibrations are set up in any elastic medium, there is always a tendency to the production of harmonic vibrations. If movable particles of matter come within the range of such vibrations, they will be driven away from the internodes and collect about the nodes. No other known medium has so great a degree of elasticity as the hypothetical æther, the medium which is supposed to produce, by its vibrations, the sensation of light. There is, therefore, an eminent reason why we should look for evidences of harmonic æthereal vibrations, provided we can find any sufficient cause for fundamental vibrations. Whether the assumed æther has a real existence or not, is a matter of no consequence. If we find an extensive series of phenomena which seem to be controlled by the laws of elasticity, we may reasonably use those laws as a help towards anticipating other phenomena of a like kind.

The wave-velocity, in an elastic atmosphere, is equivalent to $\sqrt{gh}$, or to gt, g denoting the force of gravity at the point of observation; h, the "modulus of elasticity," or the height of a homogeneous atmosphere; t, the time of fall through $\frac{1}{2}h$, under the constant acceleration g, or the time of rise through $\frac{1}{2}h$, under the initial velocity gt, and constant retardation g. If circular or elliptical orbits are produced by the alternate rise and fall which accompany such vibrations, and if the collision of orbital particles forms a rotating nucleus, the law of "conservation of areas" requires that $\sqrt{gh} = gt$ should be constant. At the centre of our system, if t represents the time of a half rotation of the Sun, gt is the velocity of light. This intimate dependence of solar rotation on light-velocity, must always have existed in the past, and will always exist in the future, through all possible stages of nebular condensation, unless there should be some contravening divine intervention.

---

[1] This Journal, Sept., Oct., Nov., Dec., 1877.

This fundamental wave-velocity is about 487 times as great as the greatest velocity that can be communicated by solar attraction. Hence the orbital velocities of planets are relatively insignificant, and each planet forms a node of comparative rest in the æthereal sea. The most important node is formed by the Sun; the most important in the planetary belts, by Jupiter, which is nearly two and a half times as great as the aggregate sum of all its companion planets; the most important in the intra-asteroidal belt, by Earth, which is in the centre of the belt, and is also the largest of the dense planets.

We have already seen[i] that a primary harmony is set up by Neptune; that it is modified by Jupiter and Saturn; that the Jupiter harmony is the most extended of any, and that even Jupiter's influence is modified by Earth. According to the nebular hypothesis, when Sun was expanded to the present orbit of Jupiter, the collisions of subsiding particles would tend to form a ring at two-thirds the distance, or at 3·469 times Earth's mean radius-vector. If we take this as a new harmonic unit, $\frac{1}{1}$, we find that Venus's mean perihelion is well represented by $\frac{1}{5}$, Mercury's mean distance by $\frac{1}{9}$, and Kirkwood's estimated semi-major-axis of "Vulcan" by $\frac{1}{17}$. Here are, therefore, four terms of a new harmonic series, with a denominator difference of 4.

These indications were so striking, especially when taken in connection with other rhythmical planetary series as to justify their announcement before the American Philosophical Society, at its meeting of May 2d, 1873.[ii] An abstract of the announcement was also published in the New York *Tribune* of the same date, special attention being called to the fourth term ($\frac{1}{13}$ of $3·469 = ·267$), as indicating

---

[i] Loc. cit.

[ii] Proc. Soc. Phil. Amer., xiii, 238, 470, 472.

"a possible unknown planet, planetoid group, or other seat of solar and planetary perturbation." Forty-one days afterwards, on the 19th of June, Messrs. De la Rue, Stewart and Loewy made a communication to the Royal Society, in which they adduced evidence of tendencies in sun-spots "to change alternately from the North, or positive, to the South, or negative, hemisphere and *vice versa*," attaching special significance to the fact "that *the two outbreaks are at opposite ends of the same solar diameter*." They assign "the most probable mean value, 25·2 days" for the interval between two maxima of the same sign. The interval between two maxima *of the same sign and originating in tidal disturbance at the same axial extremity* would, of course, be twice as great, and a planet or planetoid belt, with such an orbital period, would represent the first of the harmonic intra-Mercurial nodes. This was the fifth confirmation of my new series, and the first proper verification of my prediction.

At the time of the late total solar eclipse, Watson and Swift each observed two small planets in near proximity to the Sun. Two French astronomers, Gaillot and Mouchez, by comparing Watson's first announcement with some of the most trustworthy of the observations which have been collected by Leverrier, deduced a probable orbital period of 24·25 days, which satisfactorily represents my third intra-Mercurial position. Thus, after an interval of more than five years, comes the sixth confirmation and the second verification, both of my hypothesis and of my prediction. Could any *experimentum crucis* be more conclusive?

In "The Gamut of Light," "Planetary Mechanics," and "Elementary Spectral Harmonies,"[1] I have shown that spectral lines are harmonically arranged; that the same fundamental harmonic progression has influenced the solar spectrum and the positions of planets; that the masses of the four principal planets involve a figurate series which is also found in the arrangement of the Fraunhofer lines; and that all these results are simple consequences of the laws which govern synchronous vibrations in elastic media. In various communications to the American Philosophical Society, I have further shown that there are evidences of similar synchronism, under the influence of impulses which are propagated with the velocity of light, in heat, actinism, electricity, electro-magnetism, barometric fluctuations, terrestrial magnetism, chemical combination, and dissociation. If the energies of the earth "are all generated by a portion of the Sun's energy which does not amount to $\frac{1}{2300000000}$ of the whole,"[i] we may readily believe that the same energy which produces all these results, would suffice for the formation of cosmical nodes.

---

[1] This Journal, Sept., Oct., 1877, Jan., 1878.

If a nebula condenses until all the particles in the equatorial plane have an orbital velocity, the mean radial *vis viva* at the orbital centre of linear oscillation ($\frac{1}{3}r$), is equivalent to the orbital *vis viva* at $9r$. This equality may, perhaps, help to account for the following approximate division of the planetary system, the unit being Sun's radius:

$9^2 r = 81 r$.	Mercury's mean radius-vector,	$83{\cdot}17 r$.
$9^3 r = 729 r$.	Asteroid 76,	$732{\cdot}42 r$.
$9^4 r = 6561 r$.	Neptune's mean radius-vector,	$6453{\cdot}06 r$.

The relatively rapid motion of Phobos, the inner satellite of Mars, as well as the newly-found meteoroidal character of the corona, may reasonably lead us to look for an indefinite number of further verifications, among the results of future discovery. Many of them, like many of the Neptunian harmonies which are modified by the overshadowing mass of Jupiter, will probably elude all attempts at discovery, but the apparent importance of 9 as a cosmical factor, gives interest to the second series in the following table. The denominators, in the first series, are of the general form $(4n - 3)$; those in the second series are of the form $(4v - 3 \doteq 144n - 111)$; v being equivalent to $9(4n - 3)$.

FIRST SERIES.

No.	Harmonic Prediction.		Confirmation.	
1	$\frac{1}{1}$ =	3·469	Node of subsidence,	3·469
2	$\frac{1}{5}$	·694	Venus m. p.,[ii]	·698
3	$\frac{1}{9}$	·385	Mercury m.,	·387
4	$\frac{1}{13}$	·267	De la Rue, S., and L.,	·267
5	$\frac{1}{17}$	·204	Kirkwood,	·209
6	$\frac{1}{21}$	·165	Watson,	·164

---

[i] "Heat as a Mode of Motion," N. Y. ed., 1873, p. 466.

[ii] m., mean; p., perihelion.

SECOND SERIES.

No.	Harmonic Prediction.			Confirmation.	
1	$\frac{1}{33}$	=	·1051	Helios,	·1060
2	$\frac{1}{177}$		·0196	Themis,	·0196
3	$\frac{1}{321}$		·0108	Eunomia,	·0108
4	$\frac{1}{465}$		·0074	Phaos,	·0075
5	$\frac{1}{609}$		·0057	Lychnis,	·0056
6	$\frac{1}{753}$		·0047	Sun's surface,	·0047

The first term of the second series, Helios, represents an orbital node in which the time of revolution would be synchronous with that of a solar half-rotation. This, as I have already said, is equivalent to the time in which the continuous acceleration or retardation of Sun's superficial gravitation, would communicate or overcome *the velocity of light.* In order to maintain equality of areas, the time of rotation, in an expanding or contracting nucleus, should vary as the square of radius. But g varies inversely as the square of radius, so that $g\,t$ should be constant at all stages of solar condensation, past, present, or future.

The second term of the series, Themis, represents an orbital node in which planetary revolution would be accomplished in a sidereal day, or synchronously with Earth's rotation on its axis. The closeness of its relation to Earth, and its accordance with the laws of harmony, are both fitly designated by its name; Themis having been regarded as the daughter of Heaven and Earth, and as the goddess of law and order.

The third term of the series, Eunomia, represents an orbital node in which planetary revolution would be accomplished synchronously with Jupiter's rotation on its axis. Its designation has also a double fitness, for Eunomia was the mythical daughter of Jupiter and Themis, her name signifying "good government."

The fourth term of the series, Phaos, represents an orbital node in which planetary revolution would be synchronous with two planetary revolutions at Sun's surface.

The fifth term of the series, Lychnis, represents an orbital node at which Herschel's theoretical "subsidence" would give Sun's present velocity of rotation.

The sixth term of the series represents a node which is somewhat within Sun's apparent surface, or at its actual surface, provided the depth of the photosphere is one per cent. of Sun's radius.

The one hundred and eighty-seventh term of the first series represents an orbital node at the upper surface of Sun's photosphere. Its harmonic denominator represents the ratio of Sun's mass to the aggregate planetary mass.

We see, therefore, in the second series, not only the nodal influence of the largest two bodies in the system, Sun and Jupiter, but also an accordant influence of our own planet, which is the central orb and the largest planet in the belt which is bounded by the secular perihelion of Mercury and the secular aphelion of Mars.

Herschel's modified presentation of the nebular hypothesis furnishes the needful grounds for a satisfactory explanation of such remarkable velocities as that of the inner moon of Mars. It also seems to require that secondary orbs, when they revolve in less time than is required for the rotation of their primaries, should be denser than the primaries. There is, therefore, good reason for the further prediction that, whenever the density of Phobos is ascertained, it will be found to be greater than that of the planet itself. If Mars has any other moons which have an orbital period of less than twenty-four hours, they should also be of like superior density. In these harmonies, as well as in many others, the pointing to the primeval organizing agency of light is interesting and suggestive. At the theoretical period of each of the harmonic divisions, and at all other stages of nebular condensation, the rhythmical rotation of our day-star has been repeating its unvarying confirmation of the old, old record. In the dim and distant past, in the living present, and through all coming time; from the great "Beginning," until the culmination of prophecy when "the elements shall melt with fervent heat;" nothing but Divine intervention has disturbed, or can disturb, the equality between the accumulated action of solar gravity for a half-rotation and the velocity of light. The harmonic hypothesis forecasts the same requirement, at the surface of the central orb in every stellar system, so that the closing refrain in the hymn of each of the morning stars, is, was, and ever shall be:

> "And God said, Let there be light; and there was light."

NOTE ON THE POWER OF WATER TO HOLD MATTER IN SUSPENSION.

By Clemens Herschel, C. E., of Boston, Mass.

I desire to offer a few remarks, partly in answer to Mr. Frizell's note, in the September number of this Journal, and partly in extension of my own paper, in the numbers for May, June and July. Says Mr. Frizell, criticising M. Dupuit's Theory: "Force or pressure is *tendency to produce motion*. There can be no unbalanced pressure in a mass of water without a corresponding motion. Yet the theory only contemplates a horizontal movement from *A* towards *B*."

It is not, perhaps, my part to defend the theories of M. Dupuit, but it may be of interest to the readers of this Journal for me to say that I do not read M. Dupuit in the way Mr. Frizell does. I think M. Dupuit not only contemplates, but says he has observed, the *motion* at right angles to the general flow of the stream, produced by the unbalanced pressure of contiguous filaments of water. In speaking of their *upward* pressure, as suspending solid matter, he compares it to the lateral pressure which draws a floating body from the shore into the thread of the current. This, certainly, is a case of *motion* caused by unbalanced pressure laterally.

Says Mr. Frizell, a little further on: "A solid particle heavier than water, and suspended therein, never ceases to sink with the full velocity determined by its size and specific gravity." And Mr. Frizell has clearly shown how a body of 1 ft. diameter, will sink at the rate of 9·17 ft. per second, when diameters of ·01 ft. and of 0·000000000229 ft. will sink at the rates, only, of 0·917 ft. per second, and 6 in. per hour, respectively. But let us suppose a vertical velocity in the water of only 0·918 ft. per second, and of 6·1 in. per hour, and the bodies named will at once cease to sink, and will begin, instead, to rise. It is a precisely analagous case to Mr. Frizell's clever method for compressing air. Bubbles of air, it might have been said, never cease to rise; but Mr. Frizell has shown us, that when enclosed in water moving at a proper velocity, they are carried downwards and are compressed. Similarly, the particles of clay, and even gravel stones, though ordinarily never ceasing to fall, are made to rise by an upward current of water.

That such upward currents actually exist, may be clearly proven. While I have been delaying the writing of this much of this note, Mr. James B. Francis, Engineer of the Proprietors of Locks and Canals on Merrimack River, has published, in the Transactions of the American Society of Civil Engineers, the results of experiments made by him years ago, in which this vertical velocity of the water could be observed, and in a number just issued he calls attention to the fact that herein lies the explanation of the power of water to hold matter in suspension. Again, a German engineer, Mr. Harder, has recently published a new theory of the movement of water in rivers and canals, in which it is shown by *analytical* reasoning and calculation, that the lower layers of water are constantly rising to the surface, even in the case of water flowing uniformly. The fact is, that the theories of water flowing in rivers and canals, which suppose only a horizontal movement of the particles moved, are every one of them based on a snare and a delusion, and it is probable that they will be universally modified or abandoned before very long.

I desire, in conclusion, to offer some suggestions as to how experimental proof, and measurement as well, of the vertical motion of flowing water could be obtained. A properly constructed current-meter will measure the component of the velocity of the water in line with its axis of rotation. It will measure velocities as low as 0·15 ft. per second, and I think can be made to measure as low as 0·10 ft. per second, holding the instrument in one spot. But by moving the meter with a known and uniform velocity, first with the current to be measured, and then against it, I have measured a velocity of only 0·02 ft. per second. Working in this way, the vertical component of the velocity could readily be ascertained; likewise the horizontal velocity, and, from the two, the velocity in any other intermediate line. Also, the *lateral* velocity, spoken of by M. Dupuit. I do not go into the details of this matter now, as I am preparing an account of a series of experiments made with current-meters at Lowell, Mass. They extended over two seasons, and were made with a perfection of apparatus not always at the service of experimenters. This account, it is expected, will be ready for publication in a few months.

BOSTON, *October 16th*, 1878.

ON THE COMPUTATION OF TABLES OF WEIGHTS OR VALUES OF MACHINERY OR MACHINE DETAILS.

By Robt. Briggs, C. E.

The preparation of tabular statements of the weights or the cost of details of machinery, or of machines completed as a whole, to be used as reference tables in construction, or for manufacturing or sales values, is one of the most onerous demands on the skill of the mechanical engineer.

Generally but few examples of any especial form of detail or machine are drawn out fully, or put in proper shape to be estimated upon, but even where the whole list of a number of separate sizes of details or machines are worked up, and even also when actual weights and costs are made out, there will appear discrepant results which demand to be reconciled by sound judgment, in comparisons of values, to give reliable data for future use.

The common method of correcting values is the graphic one. On a scale, where a line of abscissæ is divided to express the linear dimension (diameter or side of cube), are erected ordinates, in terms of numerical weights or values, for as many sizes as may be computed out; when the smoothness of the curve delineated by the ordinates indicates the precision of the estimates, and the corrected curve which passes nearest to several quantities or values admits of the interpolation of other ordinates, thus serving to complete the table without calling for further estimates. That these curves are expressed by some equation in the form of $C + aD + bD^2 + cD^3 + \ldots\ldots$ is easily demonstrable and may be admitted, but the seeking for such an equation involves far more trouble than the graphic method alluded to, so that the method by equation may be set aside as impracticable. But, on the other hand, it is not as generally known that by the adoption of one of the properties of the equation, a ready mode is offered of approximating to the desired values and of correcting the accidental discrepancies of weights or of costs of work. The method of successive differences of ascertained values is more easily applied in most instances than the graphic one, and it is theoretically accurate. The demonstration of this last fact is entirely elementary. Thus, if the equation is that of a straight line, or $C + aD$, it is evident that in the first difference of a series of values, C, which is the constant, will disappear, and the result will be aD; $a(D+1)$; $a(D+2)$; $a(D+3)$, etc. The supposition being that D increases 1 unit in each case in forming the table—from whence the second differences become a, $2a$, $3a$, etc., as aD disappears in this case. The next difference becomes a only for each value, and the next again zero. If the equation has the form $C+aD \times bD^2$ one more successive difference will remove all the figures and become zero. It consequently follows that if we can ascertain the value of the constant of the first, second or third, or other constant difference, we can establish an accurate table of values within the limits of our examples accepted as data. Noting that for the determination of the formula $C+aD$, we must have two values, for that of $C+aD+bD^2$, three values; for that of $C+aD+bD^2+cD^3$, four values, etc.

A numerical example of this proposition may not be out of place:

For $D=$	1		2		3		4		5		6		7		8		9		10
let $C=$	4		4		4		4		4		4		4		4		4		4
1st difference,		0		0		0		0		0		0		0		0		0	

For $D=$	1		2		3		4		5		6		7		8		9		10
let $a=5 \therefore aD=$	5		10		15		20		25		30		35		40		45		50
1st difference,		5		5		5		5		5		5		5		5		5	
2d difference,			0		0		0		0		0		0		0		0		

$C+aD=$	9		14		19		24		29		34		39		44		49		54
1st difference,		5		5		5		5		5		5		5		5		5	
2d difference,			0		0		0		0		0		0		0		0		

For $D=$	1		2		3		4		5		6		7		8		9		10
$D^2=$	1		4		9		16		25		36		49		64		81		100
let $b=3 \therefore bD^2=$	3		12		27		48		75		108		147		192		243		300
1st difference,		9		15		21		27		33		39		45		51		57	
2d difference,			6		6		6		6		6		6		6		6		
3d difference,				0		0		0		0		0		0		0			

$C+aD+bD^2=$	12		26		46		72		104		142		186		236		292		354
1st difference,		14		20		26		32		38		·44		56		56		62	
2d difference,			6		6		6		6		6		6		6		6		
3d difference,				0		0		0		0		0		0		0			

I will not pursue this to the cubic value of D, but it is evident that whatever power be taken, somewhere the successive differences will end in zero, regardless of any particular value for C, a, b, c or D which may be taken.

Take for instance cast-iron water-pipes, referring to their internal diameters as the units of dimension. To suit the conditions of strength simply, the thickness of such pipes can be held to vary as the diameters, but to satisfy the requirement for moulding, especially in lengths which are the same for all diameters (of pipes from 4 inches to 20 inches), and of running of the molten iron, some constant of thickness will appear, which will express the theoretic least thickness when the diameter becomes zero, but which, for practical use, is a larger part of the material in the smaller pipes. The formula for thickness thus becomes, $T = C + aD$, which is the expression for a straight line where a is a coefficient determined by the required strength of the pipe as related to the strength of material employed; D is any diameter of a particular pipe in inches (or other units) and C is the constant of thickness also in inches. The weight of a foot (or other unit) of length of such a pipe, with its thickness corresponding to this formula will of course be $= k\,[(D + 2\,T)^2 - D^2]$, where k is a coefficient expressing the weight of one inch round of the cast-iron one foot in length. This formula reduces to $= k\,[(a^2 + a)\,D^2 + (2\,aC + C)\,D + C^2]$ and becomes simply $= C + aD + bD^2$ with especial values for a and b. This curve can be tabulated by differences, after computing any three values of the series. If the cast-iron pipes were plain cylinders without bell or flange ends, all of the same lengths, then the weights of the several sizes would be found by the same formula; but the bells or flanges will be found to bear a relation to the length, as the *diameter of the pipes multiplied by same coefficient plus a constant* and the final cubic values of material in pipes either bell or flanged, or their weight, will vary as $C + a\,D + b\,D^2 + c\,D^3$. This system demands three accurate examples for its solution, and the fourth successive difference is zero. Again, the value of the cast-iron in the pipes does not follow the weight of the iron in each piece. Difficulties of moulding and cost of handling the material cause an increase of worth of the metal in the larger pieces on the one hand if they are relatively light, or in the smaller pieces on the other if the number of pieces to be made become large, so that another ratio of $C + a\,D$ may be needful to introduce, where either a or C may be plus or minus quantities. If this last proposition does not apply fully to the cost of cast-iron pipes, it does so decidedly for general machine-castings and machine work, so that the most used formula for a long range of values may be considered to be $C + a\,D + b\,D^2$

$+ cD^3 + eD^4$ and the fifth difference, usually a very small one indeed, is required to reconcile a set of closely-made estimates. The great excellence of the method here advanced is, that a slight examination of the conditions will allow the computer to see what order of differences are needful to give a correct result, and if the computed examples do not conform to a curve of the proper order, he can correct them without re-estimating.

ON FURTHER APPLICATIONS OF THE FLOW OF SOLIDS.

By M. Henri Tresca, President of the Societé des Ingénieurs Civiles, Paris.

(Continued from Vol. lxxvi, page 270.)

Iron, by its constitution, lends itself much better to drawing out than to setting-up. The difference is well exemplified in the case of a wagon axle which has been bent while cold. If it be divided down the centre in a plane, the fine ribbon-like appearance is clearly brought out, and the lines are very exactly concentric. In the convex portion, it might be believed that the lines were described with compasses. In the concave portion, on the contrary, the fibres are broken and confused; at the same time, there are two fractures by compression, whilst the exterior face remains entire. Here the texture would have been altered to a still greater extent, if the iron had been heated for the operation, when the metal would have been brought to a consistency like that of putty.

The deformations transversely are much better shown in a square axle 4 inches square, the surface of which had been subjected to a series of blows from a centre-punch, at intervals of 0·4 inches. The convex portion has been extended so much that the width has been reduced from 4 inches to 3·20 inches, and the concave has, on the contrary, been spread out to a width of 5½ inches, in proportion as it was shortened in length. The simultaneousness of such deformations is well known, and they are the more pronounced as the curvature is increased. But it is specially important to note, in this example, that the fissures which are produced are situated only in the compressed portion, whilst the portion principally submitted to extension has continued perfectly sound.

For the purpose of testing the soundness of the welds in rails the rails are frequently subjected to a series of torsional stresses in two opposite directions, which usually result in a number of longitudinal fissures of greater or less length, in the lines of separation of the component bars. But, in operating on a shaft turned out of a square bar of good iron, much more conclusive results are obtained. By the application of excessive torsional stress, the fibres are forced into relief, and the iron shaft absolutely assumes the form of a rope, in which all the exterior fibres are apparent. But the constitution of the interior of the shaft is still more remarkable. If a transverse section be taken it is easy to discover, by the agency of oxidation, the sinuous lines which correspond to the exterior helices, and of which the equation is precisely given by calculation, assuming that the angle of torsion is constant for all points of the shaft.

Supposing such a piece were to be raised to a welding heat and forged anew, it can scarcely be doubted that an iron of exceptionally great resisting power would be produced, possessing in some degree the best properties of metallic cables.

The ribbon-like constitution is never better manifested than in iron plates, in which it might often serve to reveal the mode of manufacture. In iron tubes, for example, which are manufactured mostly in England and in France, the regularity of the lines is such that it is only interrupted at the weld; and a means is afforded for ascertaining whether the weld has been made by simple contact, or by lapping.

The same manufacture demonstrates also the inconveniences which may attend compression. In the section of a nut for an iron tube, it is made evident by the mode of striation that the hexagonal form is produced by drawing out from a circular section, outside as well as inside. The layers are, at some points, separated towards the angles, where it was necessary that the section should be enlarged by squeezing or compression.

The object to be kept in view in the various methods of forging should be, according to the foregoing discussion, to dispose the fibres in the direction which best accords with the use to which the piece is to be applied. Mr. Haswell, director of the workshops of the Southern Railway at Vienna, has attained this object by stamping in dies piles which are suitably prepared. The author has had oxidized several of the pieces manufactured by this process for railway service; and it is clearly manifest that, though, here and there, the silicates occupy too much space, and are not regularly diffused, the fibres are nevertheless arranged in the most favorable direction in all parts of the section.

At several other iron works, the example of Mr. Haswell has been followed, in the manufacture of pieces by stamping, particularly at the iron works of Niederbronn. But no doubt iron of the best quality should be employed, in order to derive from this method of manufacture all the advantages which it promises.

The defects of the system are well exhibited in the section of a key, forged by the stamping process from a bar of iron doubled twice over on itself.

In all operations to which iron is to be submitted it is important that the particular form of its constitution should be regarded. The excellent iron plates of Berry, which may be easily doubled, because their different layers are not sufficiently susceptible of being welded, could not, for instance, be subjected to the American mode of punching, with a punch which, being faced with a helicoid surface instead of the usual flat surface, manifestly tends to tear, at the edges of the hole, the different parts of the same layer.

Heat Developed in Forging.—The study, geometrically, of the deformations produced by forging considered under the simplest conditions, has led, from another point of view, to results which, though they are not translated into definite figures, are nevertheless of some interest, whether having regard to the deformations themselves, or to the calorific phenomena by which they are accompanied.

When a square bar of iron is compressed between two horizontal flat jaws, equal and opposite to each other, the bar is flattened and elongated, and the experiments already made on the crushing of metal disks afford grounds for believing that each vertical fibre of molecules is deflected into a sinuous form, analogous to the forms produced by the crushing of a cylindrical block consisting of a pile of plates. When a prism is partially flattened the flow of the material placed under the tool is resolved into an elongation having a curved surface, which the directrix is a logarithmic curve. The equation of the curve might be given, but it is useless to enter here into theoretical speculations. It will suffice, meantime, to mention the result, and to apply it where necessary in the course of the discussion.

In a special example of deformation obtained on a bar of lead by the blow of a hammer, the distortion very much resembles those which have been already illustrated.

If each of the four faces of the prism be divided into squares of one centimetre, or 0·40 inches wide, the comparison of the figures will show all the changes which take place on one of the sides. A small enlargement of 0·12 inches is produced on the upper face and the lower face, but this may be neglected at first. Towards the middle of the depressed portion the intermediate horizontal lines present their convexity in contrary directions towards the centre-line; and the two verticals near the centre vertical have on the contrary their maximum separation from each other at the level of the centre.

The two opposite squares, having a width of 0·12 inches, show respectively two symmetrical depressions; but it is the four squares formed by the diagonals which manifest the most complicated distortions. In proportion to the depression produced, the subjacent matter is expelled both transversely and longitudinally; but the second displacement is that which it is most important to take into consideration, with respect to the elongation to be produced, and it is the only displacement which can take place, when the piece is forged by stamping.

The elongation in the interior of the compressed portion being gradual, the depressed edge resulting from it necessarily presents an inclined face. It would theoretically take a logarithmic form, of which the curve would unite nearly at right angles with the original face above, which is displaced longitudinally, and, at the bottom of the depression, with the depressed portion of the same original face. This exterior side of each of the original faces of the square is thus drawn into a form analogous to that of a letter Z, of which the inclined member has been bent over in the opposite direction. The three other sides, elongated or shortened, constitute the locality of the greatest deformations; and it is to this to which the whole attention should be directed. The original lines, as well as the resulting deformations of these lines, are illustrated with absolute exactness by a figure.

It is thus shown what takes places under the action of the first blow of the hammer. The second blow should cross the first blow, when it is required to reduce the height for the whole length of the bar; and an idea may be formed of the new deformations and the re-straightenings which take place, by examining the figures, in which the dividing lines are reproduced after each of three or four successive blows, one after the other. In spite of the care which was taken, the deformations are not sufficiently symmetrical, but they are characteristic enough to remove any doubt as to the distribution of the molecular action to which every part of the mass has been submitted.

The forged bar presents extended portions, and compressed portions, and the result of the work would evidently be the best possible if the vertical lines, successively deformed in two different directions, resumed a rectilinear arrangement after each deviation. The forging would then consist of a methodical series of the effects of deformation, immediately followed by the effects of a corresponding rectification.

Such effects become still more complex when the bar to be forged is not sustained between lateral guides by which all lateral extension is prevented. It is evident that new deformations will be presented under such conditions, which will modify those which have just been analyzed, and attention should be directed more particularly to the semi-circular protuberances which are distributed over the length of the piece, in correspondence with each blow of the hammer. These nipples form a kind of network produced by the forging, describing on the lateral surface a series of lozenges with curved sides, separated by the half circles already mentioned.

These undulations of the surface, which are of no importance in the geometrical operation of forging, nevertheless deserve notice, as they indicate the zones of maximum sliding, which are also the zones of the maximum development of heat; and the author has been enabled, by their indications, to connect the phenomena of forging with those of thermodynamics. It has long been known that heat is developed by the forging of a metal, and in some operations connected with the *platinage* of steel, pieces of steel subjected to blows rapidly delivered, may be raised to a dark-red heat. This phenomena does not ordinarily take place, except in working thin sheets; and it will be shown that, in working thicker pieces, the precise situation of the greatest development of heat can be recognized.

In a forging operation which the author has had to conduct on a large scale on an alloy of iridium with platinum, a phenomenon occurred incidentally which engrossed his whole attention, bearing intimately as it did on the deformation of solid bodies. He may be permitted to refer to it, though the experiments are not yet completed; and it will be a source of great satisfaction to him to make known the first results of these experiments to an assembly of English engineers before any publication of them elsewhere.

On the 8th of June, 1874, the author simply announced the main fact at the Academy of Sciences, that when the bar of platinum, after having been forged, had cooled to a temperature below that of red heat, it happened several times that the blows of the steam-hammer which at the same time made a local depression in the bar and lengthened it, also reheated the bar in the direction of two lines inclined to each other, forming on the sides of the piece the two diagonals of the depressed part; and this reheating was such that the metal was in these lines fully restored to a red heat, so that the form of these luminous zones could be clearly distinguished. These lines of augmented heat remained luminous for some seconds, and presented the appearance of the two limbs of the letter X. Under certain conditions as many as six of these produced successively could be counted simultaneously, following one another according as the piece was lifted under the hammer so as to be gradually drawn down for a certain part of its length.

The appearance of these luminous traces can be explained beyond all doubt. They were the lines of greatest sliding, and also the zones of the greatest development of heat—a perfectly definite manifestation of the principles of thermodynamics. That the fact had not been observed before was evidently owing to this, that the conditions necessary to be combined at the same moment had not been present under such favorable circumstances. Iridized platinum requires for its deformation a large quantity of work to be expended upon it. The surface takes no scale, and is almost translucid when the metal is brought up to a red heat. The metal is but an indifferent conductor of heat, and its specific heat is low. All these are conditions which are favorable for rendering the phenomena visible in the forging of this metal, whilst it has remained unobserved with all others.

Although this explanation was what was to be expected, the author nevertheless proceeded to justify it by experiments of a more direct character, of which some account will now be given; and which constitute the chief motive, and it may be added the chief point of interest in this communication.

Given a bar of metal at the ordinary temperature, if, after having coated it with wax or with tallow on two faces, it be subjected to a single blow of the steam-hammer, the wax melts where the depression is produced, and it is observed that the melted wax assumes in certain cases the form of the letter X, as was observed in the case of the platinum bar. In other cases the limbs of the cross are curved, presenting their convex sides to each other. The heat has then been more widely disseminated, and the wax melted over the whole of the interval by which the curves are separated.

The prism which has this melted outline for base, and for height the width of the bar, represents a certain volume and a certain weight; and if it be admitted that the whole piece has been raised to the temperature of the melted wax, the elevation of temperature represents a certain quantity of heat, or, in the ratio of the mechanical equivalent, a certain quantity of internal work which is directly exhibited by the experiment. In comparing this work with the work done by the fall of the hammer, a coefficient of efficiency is obtained which amounts to not less than 70 per cent. This value cannot be taken as final; it depends upon the conductibility of the metal, on the stiffness of the apparatus, on the clearness of outline of the melted surface. But what the author is desirous to impress upon the meeting is that here there is a return to the first methods of Mr. Joule, and that the author's investigations of the flow of solids conduct him to certain thermodynamic demonstrations.

The following are the numerical data for some of these experiments, together with the illustrative figures:

Name of Metal.	Work of the Ram.	Form of the Impression.	Area of Wax melted.	Thickness of the forging.
	kgm.		sq. cent.	cent.
Iron, ...	80	Rectangular.	1·65	2·5
"	90	"	1·50	2·5
"	110	Wide-spreading.	2 20	2·5
Copper, ...	60	Rectangular.	1·75	2·0

Volume of the corresponding prism.	Corresponding number of heat-units (heating to 50 deg. C.)	Equivalent work at the rate of 435 kgm. per caloric.	Proportion percentage of total work converted into heat.
cub. cent.		kgm.	
3 63	0·1498	63·72	0·796
3·75	0·1544	69·79	0·731
5·50	0·2269	96·44	0·877
3·50	0·1329	56·48	0·942

In the last experiment, taking as melted the area of wax included between the hammer and the crosses, a useful effect of 94 per cent. is obtained.

Stamping.—The object of stamping is to dispose the relative displacement in given directions, in order to pass from the primitive form, supplied direct by the maker, to the definitive form, which is desired to be accomplished. From this point of view, the die is a kind of channel designed to facilitate the flow of the material, and to guide in the most suitable direction or directions.

When it is required to draw down by stamping a square bar of iron, each blow of the hammer causes transverse enlargement as well as elongation; and the useless enlargement is advantageously obviated if it be prevented by the presence of the sides of the canal. If it be well to employ the stamp in simply drawing down a bar, how much more indispensable is it when the variation of form is more complex? The simple idea of flow supplies material for forming a rational judgment on the successive dispositions of the stamps required for the intermediate operations; and also on the adjustment of the sections of rolls, which are but circular stamps or moulds, by means of which iron is drawn out.

That all these phenomena are but various forms of flow, of which in most cases the circumstances can be anticipated, may be shown by other experiments which will now be described.

The most characteristic of these experiments is, perhaps, the following: Having completely effaced the reverse in relief of a piece of money, place the flat surface on a sheet of lead, and flatten the second face in the stamping press. The whole relief of this face will be produced on the face which had been reduced to flatness; and the design of this relief will even be imprinted on the lead. This effect is explained by the circumstance that each vertical thread or fibre of molecules, being separately compressed in the direction of its length, flows, when struck, with greater facility into the lead than into the other parts of the piece. The saliencies, as reproduced, are less, no doubt, than in the original relief, whilst the more delicate features are partially obliterated, but the general effect is reproduced, and it is apparent that the flow takes place in the direction of the depth, which is also the direction of least resistance.

On the reverse of the sheet of lead, which has necessarily been reduced in thickness by the effect of the imprint, the image will be found repeated in a more confused manner, and it may be distinguished by a peculiar tint, which indicates a well-defined geometrical transformation; the lead having flowed in a horizontal direction, as the only way of escape when its surface was depressed. This amplification or enlargement takes place in the proportion of 22 to 13, when the plate of lead is $\frac{1}{8}$ inch thick.

[To be continued]

MEMOIRS ON THE LIQUEFACTION OF OXYGEN, THE LIQUEFACTION AND SOLIDIFICATION OF HYDROGEN, AND ON THE THEORIES OF THE CHANGES IN CONDITION OF BODIES.

By R. Pictet.

[Continued from Vol. lxxvi, page 239.]

V.—Liquefaction and Solidification of Hydrogen.

After having obtained the foregoing results with oxygen gas, we were naturally led to treat hydrogen in the same manner. The entire mechanical apparatus used for the first gas could be used for the second without alteration.

It was merely necessary to decide upon a thoroughly understood chemical method of generating "pure hydrogen," without water and without a trace of a foreign gas, and at the same time leaving a "non-volatile residue" in the flask. These two conditions are indispensable if we desire to proceed with any accuracy, and do not wish to complicate the indications of the experiment by introducing factors whose influence it is impossible to measure. For this reason I rejected the methods depending on the decomposition of water, either by means of the alkaline metals or the pile; and I adopted the following method, by the advice of Professor Monnier.

M. Berthelot, Professor at Paris, in a synthesis of oxalic acid and formic acid, has shown that if formate of potassa be mixed with caustic potassa, and heated to 225°, absolutely pure hydrogen is obtained, without any trace of water, or of a foreign substance. The following is the formula which explains the reaction:

$$4\ CHO^2K + 2\ KHO = C^2O^4K^2 + 2\ CO^3K^2 + H^6.$$

Adding an excess of potassa, the following reaction takes place:

$$C^2O^4K^2 + 2\ KHO = 2\ CO^3K^2 + H^2.$$

Total hydrogen, H^8.

The residue consists solely of carbonate of potassa, which remains in the flask and is not volatile.

The preliminary experiments made in the laboratory gave very satisfactory results. The reaction progresses unintermittently and the temperature remains stationary at 225°.

The following is the charge of formate of potassa and potassa we placed in the flask for the first experiment, made on Thursday, Jan. 10th, from 7 to 9 o'clock P. M.

Formate, $CHO^2K = 1261$ grammes.
Potassa, $KHO = 500$ grammes.

The whole was previously heated to 150°, to drive off every trace of water and to afford absolute certainty of the purity of the mixture. The flask itself was heated to 150° to avoid the influence of humidity in every possible manner. These preparations accomplished, the flask was secured in its place and the operation commenced.

The sulphurous acid pumps condensed the protoxide of nitrogen regularly as in the preceding experiments, and soon a thick hoar frost appearing on the oxygen manometer, indicated that we might hasten the liberation of the hydrogen.

The following are my notes, taken during the experiment:

8 32 o'clock.—The hoar frost is very heavy, especially on the pipes conducting the protoxide of nitrogen. The pressure of the hydrogen is 50 atmospheres.

8.34	P. M.	Pressure	60	atmospheres.
8.35	“	“	70	“
8.38	“	“	80	“
8.43	“	“	90	“
8.45	“	“	92	“

The gas flame is slightly lowered, so as not to overheat the outside of the flask, and to equalize the temperature.

8.47	P. M.	Pressure	100	atmospheres.
8.50	“	“	112	“
8.52	“	“	120	“
8.54	“	“	140	“
8.56	“	“	150	“
8.58	“	“	170	“
8.59	“	“	190	“
9.00	“	“	200	“
9.01	“	“	215	“
9.01.30	“	“	225	“
9.01.45	“	“	240	“
9.02	“	“	260	“
9·04	“	“	300	“
9.05	“	“	340	“
9.05.30	“	“	350	“
9.06	“	“	370	“
9.06.15	“	“	400	“
9.06.30	“	“	450	“
9.07	“	“	500	“
9.08	“	“	550	“
9.09	“	“	590	“
9.10.30	“	“	640	“
9.11	“	“	650	“
9.11.30	“	“	652	“

The pressure is almost stationary after having gradually risen during 40 minutes, I open the plug-cock.

The jet is illuminated by a strong electric light.

At the moment of opening, an opaque jet of a well-defined steel-blue tint is seen to issue from the orifice. The opaque portion is about 14 centimetres in length and 15 to 20 millimetres in diameter. Below this blue non-transparent part, and through a dense mist, produced by the vesicular condensation of the hydrogen, a whitish zone might be clearly distinguished, of a lighter blue than that of which it was the continuation, and sufficiently translucent to allow the strongly illuminated objects on the opposite side to be distinguished.

At the same moment we heard a sharp hissing noise, similar to that produced by a red-hot bar of iron plunged suddenly into water; then simultaneously a pattering sound on the ground, similar to that caused by grain falling on the earth.

The jet, instead of remaining continuous, as was the case with the oxygen, became intermittent, only escaping spasmodically.

Every expulsion was accompanied by the same crackling we just mentioned. After several seconds, I closed the regulating cock; the pressure was still at 370 atmospheres. This pressure dropped gradually to 320 atmospheres, then rose slowly and during several minutes to 330 atmospheres. At 9.18, I reopened the stop-cock.

An extremely short jet issued, with a violent expulsion of solid corpuscules; then, though the orifice was still left open, nothing passed out. The manometer indicated 315 atmospheres.

Seeing this entire stoppage in the ejection of the hydrogen, we immediately concluded that its solidification, in the interior of the tube, had been accomplished. So as to assure ourselves, I had the pumps which exhausted the vapors of protoxide of nitrogen stopped, and I opened the regulating-cock, so as to produce a condensation of the vapors of the protoxide of nitrogen in tube *D*.

This *manœuvre* having caused the temperature to rise, the ejection of the hydrogen recommenced in an intermittent manner, by discharges which became more and more frequent. They followed each other at half-minute intervals, retaining the described appearance. About a quarter of an hour after opening the regulating-cock, the last discharge took place, and the pressure returned to *O*.

Towards the close of the experiment we were able to ignite the gas issuing between the discharges, but at each violent ejection the flame was extinguished.

This first research affords no clue to the density of liquid or solid hydrogen, as the observations gave us no exact figures concerning the quantity of hydrogen contained in the tube at each moment. The intermission between the discharges, the partial or total congelation of the liquid hydrogen, the variations of the manometer, all these violent unforeseen disturbances entirely disarranged our observations, and we shall be obliged to recommence them with great care to obtain some conclusive figures.

Nevertheless, this experiment allows us to assume that it is possible to liquefy hydrogen under a pressure of 650 atmospheres at —140°.

This pressure in every case exceeds that of the maximum tension of the vapors of hydrogen, corresponding to —140°.

As regards the "solidification of hydrogen," it could not only have been foreseen, but even predicted on account of the light atomic weight of the body.

The latent heats of liquids are known to be appreciably in an inverse ratio to the atomic weights of their vapors. The exact formula, giving the latent heat, is as we have demonstrated it:

$$\lambda = \frac{10333\,(274 + t) \times 0{\cdot}041}{1{\cdot}293\,\delta \times 431}.$$

in which δ corresponds to limit of density; that is, to the atomic weight.

t is the temperature of ebullition.

If we now apply this formula to liquid oxygen and hydrogen, it will be seen that the values of λ for each liquid should be nearly in the same ratio as the atomic weights.

In fact, these two liquids have been obtained at the same temperature of —140° under pressures not varying much from each other. The temperatures of ebullition for each of those two bodies should not be more than 20° to 25° apart, at the most.

Designating the latent heat of oxygen by λ and that of hydrogen by λ', we should have the ratio

$$\frac{\lambda'}{\lambda} = \frac{(274 + t')\,\propto}{(274 \times t)'\,\propto'}$$

$274 + t'$ corresponds to the absolute temperature of hydrogen at the point of ebullition, and $274 + t$ is the absolute temperature of oxygen at the point of ebullition.

The atomic weights are to each other as $\frac{\propto}{\propto'} = 16$.

It is consequently "very probable" that the ratio of the latent heats will be:

$$\frac{\lambda'}{\lambda} = \frac{(274 + t')\,\propto}{(274 + t)\,\propto'} > 10$$

that is: the latent heat of hydrogen is at least ten times greater than that of oxygen.

If this hypothesis be correct, as soon as the condensed liquid can again evaporate, the quantity of heat absorbed by this change of condition is so considerable that the remaining liquid is constrained to solidify by congelation.

Starting from the ratio of the atomic weights, a kilogramme of condensed hydrogen should absorb more than 2000 calories. There is no cause for surprise, that the experiment has confirmed what thermal equations indicated as very probable, and this verification is another proof sustaining the basis on which the mechanical theory of heat is founded.

We will soon commence new experiments on the liquefaction of hydrogen, and will endeavor to collect the products of condensation so as to investigate them more thoroughly. In fact, it would be very useful to determine the physical appearance of this body which by every analogy is to be considered a metal, and which seems to have assumed that character in the experiment just related.

VI.—INFERENCES.

We cannot conclude this memoir without enumerating briefly the inferences which may be drawn from these experiments on the liquefaction of the gases, and recalling to mind the very similar results very recently obtained by M. L. Cailletet at Paris.

We have endeavored to reconcile the principal phenomena, concerning the so-called permanent gases, with the law of Mariotte, the theory of M. Clausius, the experiments of M. Regnault, and with those of M. Natterer.

The apparent antagonism shown, by a hasty investigation, between the law of cohesion and the mechanical theory of heat, disappears entirely on the introduction of a new factor which is "the length of the calorific oscillation."

In the experiments of M. Natterer, given in a table in the first chapter, we see the pressures increase more rapidly than the law of Mariotte would indicate; is this solely caused by the dimensions of the atoms or molecules of the gases, as explained by Clausius?

Certainly not, for were this cause the only one, the difference should be inappreciable up to a high pressure, sufficient to force the molecules almost into contact; then it should suddenly become very great, caused by the impenetrability of matter.

On the contrary, we see this deviation from the law of the compressibility of gases gradually increase, but pass unintermittently from a value equal naught, to a high one for great pressures. This clearly indicates that Mariotte's law is strictly true for gases, "as long as the mean distance of the molecules from each other is still greater than the length of the calorific oscillation corresponding to the temperature of the gas." As soon as this distance becomes equal to the length of oscillation, the pressure grows more rapidly than is indicated by Mariotte's law; as the caloric force now increases the pressure of the gas. If the gaseous volume be still compressed at this moment, we encounter an obstacle growing stronger and stronger as the calorific vibrations take place with an energy that no force can master.

Experiments made on the expansion of solids and liquids, prove that it exerts an energy greater than molecular cohesion. We thus arrive at a point in the compression of gases, where we find as powerful a resistance as that offered by liquids and solids.

We have said that the molecular force of cohesion must assume a certain value, K, so that the liquid condition might be produced. This value of K is a function of the temperature, equal for all liquids.

We can easily account, physically, for the necessity of such a condition:

Imagine a gaseous volume at any pressure, and assume that liquefaction has commenced. What are the peculiar physical characteristics of the condition of this vapor and of its liquid?

The liquid would evidently possess a "greater density" than that of the vapor and its surface of contact, which unites them, might be seen. The increase in the density of vapor at the moment of condensation is a proof of the closer approach of the molecules; but before condensation, did these molecules not attract each other at all?

They undoubtedly did; at each impulse two molecules were united by their force of attraction, but the temperature and the calorific vibrations corresponding to this elementary work of condensation, disengaged them at once, and prevented the liquid state from becoming stable.

In fact, molecular cohesion operating in a similar manner throughout all parts of this gaseous mass, and nowheres "with sufficient energy to render the condensation stable;" the gas retains its gaseous form.

If the number of gaseous molecules be now increased, and the temperature lowered, the separation will take place immediately in the gaseous mass, and the liquid will be precipitated to the bottom of the receptacle. The power of attraction having increased, by the closer approach of the molecules, and by the diminution of the amplitude of the calorific oscillations; when two molecules will have been united by cohesion, they will no longer find the dynamical elements necessary to escape from its influence, which will then become permanent. From this moment condensation takes place uninterruptedly, and the liquid accumulates at the bottom of the condenser.

Therefore, there is necessarily a "very sharply-defined limit" for any condensing gaseous matter. This limit corresponds to the "critical point," as it is now called. At the critical point, the molecular attraction is equal to K, a constant for all liquids at the same temperature.

The experiments described all tend to afford a positive proof of the fact, that liquids are forcibly led to the gaseous state, at a certain temperature, "whatever may be the pressure and the volume" to which they are limited.

By a very fortunate coincidence, most of the phenomena relating to the condensation of the permanent gases have been explained at Paris, at the same moment as at Geneva.

This coincidence has a double advantage, first to give a degree of absolute certainty to the phenomena themselves; then to prove that all the deductions logically drawn from the mechanical theory of heat are *completely* confirmed when transplanted from the domain of pure speculation to that of experimental physics.

By means of a most elegant and perfectly simple arrangement, M. Cailletet has furnished an indisputable proof of the liquefaction of the permanent gases. His experiments, previous to mine, are based solely on the thermal influence due to the expansion of the gases. They can be easily reproduced, and before a numerous audience.

In 1828, that is just fifty years ago, Professor D. Colladon, corresponding member of the Academy of Sciences, made numerous attempts, at Geneva, to liquefy the incoercible gases, especially atmospheric air. His apparatus, represented[1] on Plate III, was very similar to that of M. Cailletet. The following is a short description:

The pressure was produced by a hydraulic pump, transmitted through a nipple, $C\,c$, to the interior and upper part of a very strong hollow steel cylinder, B, partially filled with mercury. In cylinder B was a glass tube, T, open at the lower end, but joined at the upper end to a second tube, t', of thick glass, whose interior diameter was but 1·5 to 2 millimetres. The second tube protruded from the cylinder, B, traversing the elongated neck of cover, A, to which it was joined by gum-lake; it was afterwards bent in the flame of an enameler's lamp, and its curved extremity, t', could be chilled to render liquefaction visible if it could be accomplished. The gases experimented upon filled the whole of tube T at the beginning of the experiment.

---

[1] The principal parts of this old apparatus still exist, and have been kept for several years in the offices of the Société genevoise pour la construction des instruments de physique.

Professor Colladon experimented with temperatures of — 30° and with pressures reaching 400 atmospheres, without obtaining any result. Unhappily, the dynamic theory of heat was not yet known; but for that, on opening the water-escape cock suddenly, liquefaction of the permanent gases would have been accomplished fifty years ago.

M. D. Colladon facilitated our work by his invaluable advice, and we here acknowledge our profound gratitude.

The investigation begun in this memoir requires numerous experiments for completion. A quantity of data of every description must be accumulated to give the numerical results perfect accuracy. What we desire, above all, is, that this class of researches will cause the employment of cold to be considered, in physical laboratories, as an essential means for the study of the molecular forces. Who knows but what crystallization and certain reactions may find peculiarly favorable conditions by this means?

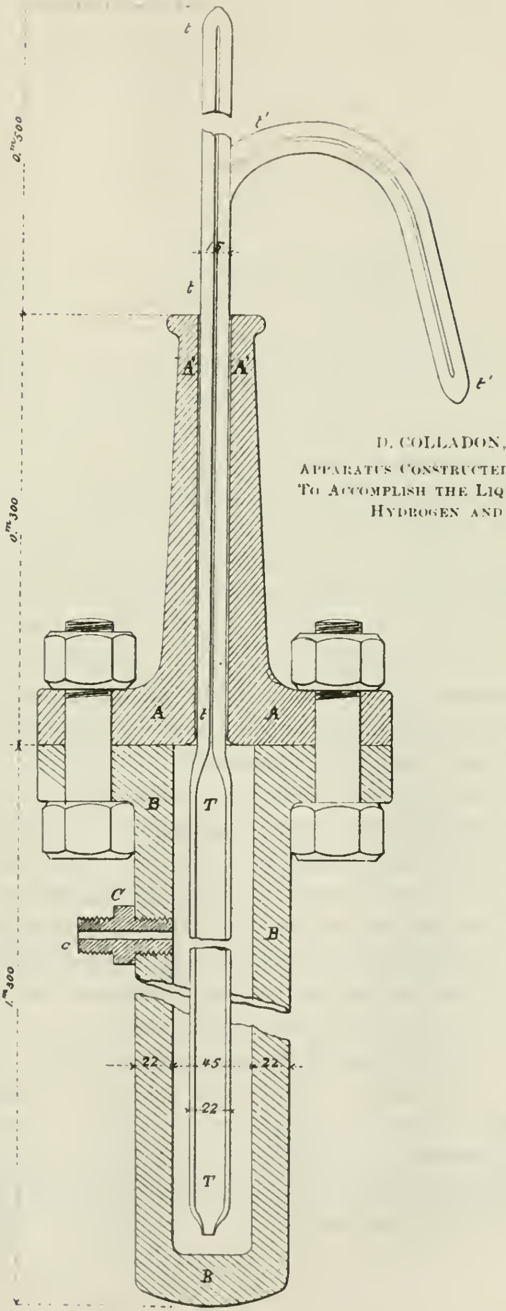
One of the principal obstacles which have stopped the majority of experimentalists, is the want of mechanical aids, they being too expensive to be at the disposal of every one. Thanks to the "Society of Geneva for the construction of physical instruments," I had at my disposal a mechanical apparatus of great value and accuracy of workmanship, which might be valued at fifty thousand francs at least. It is solely due to this exceptionally advantageous circumstance, that I was enabled to succeed in these researches.

It is much to be desired that large laboratories should have similar means at their disposal; they would facilitate a thousand works of indisputable interest, which must now be abandoned for want of proper apparatus.

This memoir will be completed as soon as our experiments shall have furnished us with new data.

Journal of the Franklin Institute, Vol. CVI.

PICTET—PLATE III.



D. COLLADON, 1828.
Apparatus Constructed at Geneva
To Accomplish the Liquefaction of
Hydrogen and Air.

D. A. PARTRIDGE PHOTO LITH. 7 S. SEVENTH ST. PHILA.

NOTE ON TWO NEW FORMS OF BELL TELEPHONE.

By Brown Ayres, B. S.

The writer some time since constructed a form of telephone belonging to the third class of magneto-telephones, according to his classification in a former number of the Journal,[1] a description of which may be of interest as illustrating how very little, mechanically speaking, is essential to the transmission of articulate speech.

The instrument referred to consisted of a ferrotype plate, to the centre of which was connected a spiral steel spring, whose axis was at right angles to the plate, and the farther end of which was connected to an adjusting-screw by means of which the tension on the spring could be varied. This spring was of a fine piano-forte wire, and was permanently magnetized by rubbing with a bar-magnet. The spring and plate were in metallic connection, so that a complete circuit could be formed through the plate, spring, adjusting-screw and outside connections. On placing in the circuit a Bell Telephone of the modified form described in the paper before referred to, and speaking against the ferrotype membrane of our new telephone, words could be distinguished in the Bell Telephone, though they were not very loud. I have thought that under favorable circumstances this instrument could be used as a receiver, motion being imparted to the ferrotype-plate by the mutual attractions of the superposed portions of the helix when traversed by a current. In this event, however, the tone reproduced would be constantly one octave above the original tone, as both of the alternating currents would produce attractions, the retrograde motion of the plate arising from its own elasticity and that of the helix. I have not yet applied it, however, as a receiver. The same ends would be accomplished, of course, by the use of a spring of any conducting material which was traversed by a continuous current, the solenoid then playing the part of magnet and conductor.

Another form of the third class would be one in which we made the ferrotype-plate a portion of our circuit, the connections being made at the extremities of a diameter, and a horse-shoe magnet being symmetrically placed with reference to this diameter in a plane through the centre at right angles to it.

---

[1] Jour. Frank. Inst., June, 1878.

In both these cases we have the simultaneous relative motion of magnet and conductor, and the form first described is interesting from the fact that the helical spring is at once the magnet and conductor.

Baltimore, *Oct.* 19, 1878.

The Part played by Coal-Dust in Producing Explosions in Mines.—L. Simonin.—The author demands permission to make known certain facts which prove that it is in the majority of cases the heating of the coal-dust diffused in the galleries of the mines to which explosions are due. Referring to the catastrophe in the Jabin Mine at Saint Etienne (February 4th, 1877) he states, on the authority of the manager, that the mine in question contains very little fire-damp, and that the precautions hitherto taken with an exclusive reference to that gas are not sufficient. Others must be taken against the extremely fine coal-dust, which at the moment of the explosion of slight amounts of fire-damp, or even of blasting powder, liberates rapidly a part of the coal-gas which it contains, and propagates the explosion, reproducing the cause of the evil with so much the greater energy as the current of air is more violent. Thick crusts of coke (2 or 3 centimetres) prove this fact and explain how it is that extensive tracts in which fire-damp has never been observed are burnt like the rest of the workings. Hence, it appears that the precautions to be taken in fiery mines are complex whenever the coal-dust is rich in gas and very finely divided. Explosions may then ensue even in mines where fire-damp is unknown. There is no need to suggest the existence of cavities full of carbonic oxide, or of gaseous hydrocarbons, and suddenly laid open by a blow from the miner's pick. [Is not the attempt, recently made in some mines, to screen the coal below ground, a dangerous mistake as calculated to increase the quantity of dust diffused in the air of the mine?—*Ed. C. N.*]—*Chem. News.* *

Retention of Heat.—MM. Blaugy, Poure & Co., manufacturers at Boulogne-sur-Mer, adopt the following plan to prevent the loss of heat in the steam-pipes, generator domes, machine cylinders, etc., of their workshops. They simply cover the surfaces with sawdust mixed with flour paste. If the paste is very liquid, if the mixture is taken in the form of a stiff dough, and if the surfaces have been well cleaned from grease, the adhesion is perfect and free from cracks. They cover their apparatus with five successive layers of five millimetres each, or a total thickness of 25 millimetres (9·84 inches), which gives them a much better result than 50 millimetres of any of the other materials which are usually employed. The cost is almost nothing; with 50 kilogrammes (110·23 pounds) of farina at an expense of about 20 fr. ($5.00), they obtain the same result as with 1000 fr. ($200.00), expended for other materials. The paste is composed of farina, without the addition of starch. The mixture can be applied by a trowel with the greatest facility, either internally or externally. If there is much exposure, two or three coatings of coal-tar render it impermeable to water. If the tubes are of copper, two or three light coats of a hot liquid solution of clay should be first applied, in order to increase the adhesion of the sawdust.—*Les Mondes.* C.

Acceleration of Nervous Velocity by the Will.—Chauveau has lately undertaken two distinct sets of experiments. In the first, he compared the velocity of transmission in the nerves of the laryngeal muscles (red voluntary muscles), and in those of the cervical position of the œsophagus (red involuntary muscles). In the second, the comparison was extended to the nerves of the terminal portion of the œsophagus (pale involuntary muscles). He finds that in the motor nerves of the red involuntary muscles, the velocity of transmission of centrifugal excitement is about eight times less than in the nerves of muscles which have an identical structure, but which belong to the portion of the muscular system that is controlled by the will.—*Comptes Rendus.* C.

Production of Steel.—Twenty years ago the production of steel, in the entire world, was little more than 300,000 tons, at an average cost of about $150 per ton. After the introduction of the modern processes of Bessemer (1860), Siemens-Martin (1868), and Pernot (1874), the production reached more than 2,200,000 tons in 1877, of which 1.800,000 tons were Bessemer metal, at an average price of $60 per ton. The remaining 400,000 tons were produced, chiefly, in reverberating furnaces, not in crucibles. The furnace steel, which in 1875 amounted to only 140,000 tons, reached 300,000 tons in 1877, and promises to increase still more rapidly than the Bessemer process has done. These few figures may give some idea of the importance which the steel manufacture has assumed, since its substitution for iron, especially upon railways, has stimulated manufacturers to increase their facilities for its production.—*Il Politecnico.* C.

Milk of the Cow Tree.—Humboldt states that, among the great number of curious phenomena which he observed, there were few which impressed his imagination so vividly as that of a tree which yields an abundant supply of milk, resembling in its properties the milk of animals. This tree, *Brosimum galactodendron*, is found on the declivities of the Venezuelan mountains. The sap is thicker than cow's milk, and has a slightly acid reaction; when exposed to the air it sours, and deposits an abundant coagulum, a kind of cheese. Boussingault has lately subjected it to a chemical examination, and finds: 1. A fatty substance similar to beeswax, fusible at 50° (122° Fahr.), partly saponifiable, very soluble in ether, slightly soluble in boiling alcohol. This material acquires, after being melted and cooled, the appearance of virgin wax, and candles have been made of it. 2. A nitrogenous substance, resembling caseine in its fibrous structure, reminding one of the vegetable fibrine which Vauquelin has lately found in the sap of the *Carica papaya*. 3. Sugary substances. 4. Phosphates and other salts of potash, lime and magnesia. Boussingault closes his communication by the following comparison with an analysis of sweet cream, by M. Jeannier:

	Vegetable milk.	Cream.
Saponifiable materials, . .	35·2	34·3
Sugary materials, . . .	2·8	4·0
Caseine and salts, . . .	4·0	3·5
Water, ...	58·0	58·2
	100·0	100·0

—*Comptes Rendus.* C.

Acoustic Gallery at Bex.—Prof. Ch. Dufour, during the last session of the Swedish Society of Natural Sciences at Bex, observed a remarkable echo in the church. The interior is of a rectangular form, with one end rounded. The pulpit is nearly in the middle of one of the large sides of the rectangle. Persons in front of the pulpit hear a speaker, at its foot and a little to the right, with great difficulty; but an auditor standing at two or three metres from the middle of the rounding part hears, with remarkable distinctness, the slightest words which are spoken at the foot of the pulpit. Dufour considers this effect more remarkable than the one in the cupola of St. Paul's, at London, and than that in the halls of the Conservatoire des Arts et Metiers, at Paris.—*Bull. Soc. Baud.* C.

Waters of the Danube and the Aach.—A curious experiment has lately been made in order to decide a dispute between manufacturers, some of whom used the waters of the Danube and others that of the Aach, a tributary of Lake Constance. The distance which separates these two rivers is about 14 kilometres (8·7 miles), and the sources of the Aach are 150 metres (492·12 ft.) lower than the surface of the Danube; the latter runs over a calcareous bed having the same inclination as the line which would join the Danube to the sources of the Aach. As the bed of the Danube is cracked, and as it was noticed that that river lost a considerable part of its waters in this region, it was natural to suppose that the Aach was fed by the infiltration. The mill-owners upon the Danube, whose water failed in times of drought, wished to maintain the level, and sought to prevent the escape by filling up the crevices. The proprietors of the Aach objected to this on the ground of its interfering with their supply. It was, therefore, desirable to ascertain whether the supposed connection really existed. Prof. Knapp placed ten thousand kilogrammes (22,046 pounds) of salt in a cavity of the bed of the Danube. Analyses of the waters of the Aach, repeated at different intervals during a number of hours, showed that they contained an unusual proportion of salt. M. Tenbrink proposed to use the coloring power of fluorescine, which is so great that one part can be recognized in twenty million parts of water. On October 9th, 1877, at 5 P. M. about fifty litres (52·83 quarts) of a solution of fluorescine were poured into the Danube. On the 12th of October observers noticed that the waters of the Aach were colored. It had required 60 hours for these colored waters to traverse the intervening soil. The coloring increased during that day, from the morning till the evening, and was plainly visible until the following day at 3 P. M. Although this process can have few applications, it could be usefully employed in some special circumstances, and it is therefore proper that it should be placed upon record.—*Ann. des Ponts et Chauss.*

[The mean subterranean velocity of the colored water was only about 766 feet per hour. It seems probable, therefore, that there were numerous caves, which must all be tinged by the flourescine before any traces of it could be seen in the Aach. In calcareous beds such caves are of frequent occurrence.] C.

Adhesion of Laminated Metals.—M. Felix Marquet applied to M. Tresca for advice as to the possibility of producing air-tight adhesion by simple pressure upon tin plates. He was referred to M. Thomaset, the inventor of a new hydraulic press, by means of which extraordinary pressure can be obtained. Finding that there was no adhesion, even after a pressure of many hundred atmospheres, Marquet used a stopping wire between the edges of the plates, and thus secured an air-tight joint as staunch as if they were soldered together. —*Les Mondes.* C.

Platinum Plating.—Great difficulties have been experienced in securing a platinum deposit of uniform color and sufficiently adhesive to secure copper and other metallic vessels from the corrosive action of acids. Böttger recommends a solution of freshly-precipitated, well-washed double chloride of platinum and ammonia in a tolerably strong boiling solution of citrate of soda. By using two strong Bunsen elements with such a solution, a beautiful, brilliant adhesive coating of pure platinum may be secured.—*Dingler's Jour.* C.

Spectroscopic Temperatures.—A. Crova has measured the calorific intensity of different portions of spectra, by means of a thermo-electric pile and a very sensitive galvanometer. Representing by 1000 the calorific intensity which corresponds to a red ray with a wave-length of 676 millionths of a millimetre, he gives the following table:

Wave-lengths, .	676	605	560	523	486	459
Sun-light, . .	1000	820	760	670	540	460
Electric-light, .	1000	707	597	506	307	228
Drummond-light, .	1000	573	490	299	168	73
Standard lamp, .	1000	442	296	166	80	27

The electric-light was derived from 60 large Bunsen elements, with Carré's carbons, in the focus of a concave metallic mirror; the standard lamp was filled with colza oil. Crova concludes that temperatures can be rigidly determined by the spectrometric method, as soon as we have ascertained the exact law of emission for all the rays and the numerical constants for each wave-length. He presents these results as a first essay towards the solution of this important question.—*Comptes Rendus.* C.

Safeguards against Boiler Explosions.—In the Congress of Civil Engineers, at the Paris Exposition, Testud de Beauregard suggested the use of suitable thermometers or galvanometers to give timely warning of any dangerous disturbance of thermal equilibrium, whether between the boiler and the water or between the water and the steam. Even if the warning should not be given in time to prevent an explosion, it might be the means of saving the lives of engineers, operatives, bystanders or neighbors.—*La Gaceta Industrial.* C.

Artificial Diamonds.—The heirs of M. Gannal have found, among his papers, a memoir relative to the artificial preparation of diamonds by the reaction of phosphorus upon carbon sulphuret. The French Academy has placed the memoir in the hands of Vauquelin and Chevreul, for examination.—*Comptes Rendus.* C.

Large Magnet.—MM. Ducretet et Cie. exhibited, at the Paris Exhibition, a Faraday electro-magnet, which they claimed to be the most powerful that has ever been made. The coils have a diameter of 50 centimetres (19·7 inches), and a height of 60 cm. (23·6 inches). The total weight is 950 kilogrammes (2193·6 pounds). The helices are made up of numerous parallel and separately insulated wires, in order to facilitate different combinations, both in tension and in quantity.—*La Nature.* C.

View from the Giffard Balloon.—At the height of 150 or 200 metres (492 to 656 feet), the whole of Paris can be seen. By ascending 400 or 500 metres (1312 to 1640 feet), the great city, reduced to Liliputian proportions, appears in the centre of a vast circle of verdure, which comprises four "departements," and which has a diameter of 120 kilometres (74·566 miles).—*La Nature.*

Telephonic Determination of the Magnetic Meridian.—M. H. de Parville substitutes a bar of soft iron, at least 1 metre (39·37 inches) in length, for the short magnet of an ordinary telephone. The apparatus still transmits sounds, but with an intensity which varies with the direction of the bar, the sound being most intense in the receiver when the transmitter is parallel to the dipping needle. The sound is more or less completely extinguished when the transmitter is perpendicular to the magnetic meridian. If such a telephone is provided with a resonator, it can be used not only to find the direction of the magnetic needle, but also for the approximate determination of the variations in magnetic intensity. This method seems applicable, on ship-board, for the correction of the compass, especially when the indications of the needle may be deceptive, on account of the neighborhood of magnetic rocks, or of islands rich in iron ores. The inventor also suggests the use of a bar of soft iron, several metres in length, having, at one end, a magnetic coil with a self-registering apparatus. The pitching of the vessel would excite induction currents, and the diagram on the register would reveal the direction of the vessel, so as to check the indications of the compass.—*Comptes Rendus.* C.

Comparative Wear of Iron and Steel Rails.—Near Oberthausen, on the line from Cologne to Minden, a variety of rails were laid in 1864, and taken up in 1876. The traffic was very great, and the percentage of replacement in twelve years was as follows: Wrought iron rails, from the Frederich-Wilhelm works, 80·66; wrought iron, from Phœnix works, 68·00; puddled steel, of Funke & Co., 33·33; puddled steel, of Hosch & Sons, 33·33; Hosch & Sons' Bessemer, 4·70; Krupp's Bessemer, 4·08; Hörder-Verein Bessemer, 1·33.—*Annales Industr.* C.

Composition of Ancient Glass.—Peligot has lately been engaged upon various analyses of glass, and turned his attention especially towards some of the oldest specimens that he could find. There is considerable difference in the composition of modern glass in different districts, but all manufacturers agree in employing three materials, lime and silex being almost invariably used, with either potash or soda as a flux. The glass-makers of antiquity used only sand and an alkali, and this is one reason why their glass had so little durability. The credit of inventing flint glass, or the modern crystal, is due entirely to the English.—*Ann. de. Chem. et de Phys.* C.

Harmonic Striæ.—C. Decharme has studied the relation which exists between the breadth of the striæ, which are produced in a thin layer of water upon a vibrating circular plate, and the number of corresponding sound-vibrations. Photographing the net-work of nodes and internodes, and measuring the striæ, he finds that their breadths are inversely proportional to the square-roots of the numbers of vibrations in the corresponding sounds.—*Comptes Rendus.* C.

A New Stone-Dressing Machine.—*Der Maschinen Constructeur*, No. 18, gives a short description of a new tool for dressing stone, which is now on exhibition at Paris, built by Brunton and Trier, Batersea Foundry, London, England.

A large, hollow face-plate is bolted to a hollow spindle, which is rotated by means of a pulley fastened to the same. The face-plate carries, near its outer edge, a number of small disks, placed at an angle to the central axis, and which have a double motion—firstly, around the axis of the main spindle, and then around their own. The mechanism is arranged to let a point of the disk's sharp edge describe a curve of a cycloidal nature on the face of the stone. There is, consequently, but little friction, which is very evident to the observer, as no sparks are visible, even while operating on the hardest material. The disks retain their sharp edges for a considerable length of time, and do not even heat.

Through the hollow spindle runs a solid one, carrying a bevel gear-wheel, which is inside the face-plate, and does not rotate, as a rule, but gives motion, through separate bevel-pinions, to the disk-spindles, whose bearings are in the face-plate. When, however, the diameter of the disks has been reduced by grinding, so as to impair the cycloidal nature of the curve before mentioned, it is necessary to give the central wheel a slow motion, to correct the error. The whole can be fed to and fro in the direction of the axis, to regulate the depth of the cut.

The machine is provided with several tables, which, besides the ordinary sliding surfaces and rack for propulsion, also have wheels, allowing the tables to be changed, and the work to go on uninterruptedly.

The machine on exhibition can dress a surface 1·4 metres (4 ft. 7·1 in.) wide, the length depending only on the length of the table or bed. The face-plate makes 100 revolutions per minute, each of the 12 disks, 600. The diameter over the outside of the disks is 1·8 metres (5 ft. 10·9 in.).

Owing to the high rate of speed, the disks, 30 cm. (11·7 in.) in diameter, can be made of very hard, chilled cast iron.

An idea of the capacity of this machine, may be gained from the following data :

1 sq. metre = 10·77 sq. ft. of granite, was dressed in 4 minutes.
" " " hard limestone, " " 2½ "
" " " sandstone " " 2 "

A cut 3 to 4 cm. (1·2 in. to 1·6 in.) deep, can be taken. P.

Cobalt in Electro-Metallurgy.—In studying some of the properties of magnetic metals obtained by means of galvanism, the attention of M. Gaiffe was attracted by the beauty of cobalt, and its hardness, which is much superior to that of iron and nickel; and the thought struck him that it might be possible to utilize this metal under certain circumstances, should it be found as easy to deposit it by the battery as it is the metals just mentioned.

It is well suited, for instance, to take the place of iron and nickel as a protective coating for plates used in copper-plate engraving. It does not oxidize like iron, and demands but little care for its preservation; it is dissolved with the greatest ease by weak acids which do not attack the copper, while nickel deposited on a copper plate cannot be renewed without injury to the latter. Its beautiful color will also cause it to be used for the decoration of other metals. The bath with which M. Gaiffe obtained very beautiful specimens was a neutral solution of double sulphate of cobalt and ammonia, which requires for its preparation scarcely as much care as baths of nickel. The anode may be a sheet of platinum, or, better yet, a plate of cobalt, either cast or forged. In this, cobalt differs from iron and nickel, which are soluble in thin baths only when they are in contact or combination with a body that is electro-negative with respect to them. In order to obtain a white, adherent deposit, the electric current should be regulated in the beginning at 6 volts, and should be reduced to 3 volts when the whole surface of the piece to be covered has become white. With a proper intensity of current, the deposit of cobalt takes place almost as rapidly as that of nickel. In four hours a layer of cobalt 0·025 millimetre thick may be obtained. When it is desired to obtain a very regular deposit, it is indispensable to fix the object to be "cobalted" to the electrode of the battery before immersing it in the bath. Without this precaution there would be produced an appearance of marbling, only removable by recommencing the process.—*Scientific American.*

Transmission of Minute Sound-Waves by the Telephone. —In the course of some experiments on a telephone line, with a view to decrease the crackling due to atmospheric disturbance, an observation was made by Prof. Frazer, which will serve to illustrate to what an infinitesimal motion the sounds heard through the telephone are sometimes due. A telephone was selected, in which the diaphragm was held fast along a circular rim, instead of the flat surface, which usually binds the outside of metal plate. It was found to resound to one note (middle A of piano).

On sounding this note clearly into the mouth-piece, while keeping the other telephones covered, so as not to be directly affected by the air-waves, it was found that the overtones, so very manifest in the vibrations of such metal disks, were distinctly traceable in the other telephones, with which connection was had over a line of about one-third of a mile, with a ground return-circuit.

It is difficult to understand that the minute waves into which a metal plate is thrown by a vigorous note of the voice, can reproduce sound through the intermediate agency of maxima and minima of conductivity, in the medium of current transmission; but that the minute wavelets which are produced upon the backs of these, should each result in fluctuations of conductivity of sufficient power to impress themselves as sounds at the extremity of a long line, could scarcely have been foreseen. The experiment was only tried with the telephones in the same room, and has not yet been verified by distinguishing the overtones in the more remote instruments.

ANOTHER VERIFICATION OF PREDICTION.

The following note was received since Prof. Chase's article on "Astronomical Forecasts," page 314, was printed.—Eds. J. F. I.

Haverford College, *Oct.* 26, 1878.

Editors Journal Franklin Institute:

Gentlemen,—Gaillot's computed orbit for Watson's second intra-Mercurial planet represents another term of my harmonic series:

Gaillot (*Comptes Rendus*, Sept. 30), . .	·1803
Chase ($\frac{1}{19}$ node of Jupiter-subsidence), . .	·1826

Yours, truly, Pliny E. Chase.

Book Notices.

AN ELEMENTARY COURSE OF CIVIL ENGINEERING. By J. B. Wheeler, Professor of Civil and Military Engineering, U. S. Military Academy. 8vo, pp. 472. J. Wiley & Sons, N. Y.

It is impossible to include within the compass of one volume of four or five hundred pages, a satisfactory elementary review of the various subdivisions of civil engineering, as practiced at the present day.

Professor Wheeler has doubtless been impelled to make the attempt by the necessities of his scholars, and the limited time allotted to pure civil engineering at West Point, and has given to the public a very ably compiled volume.

The reader of this work, however, gets but a glimpse of the vast field of industry which lies before him in each subdivision, and the usefulness of the work would be increased very greatly, by careful references to the various sources from which the information here given has been derived, thus enabling the reader to follow the clue given by a short reference, and obtain a thorough knowledge of whatever department of engineering he may, for any reason, be desirous of knowing more.

Part I, on building materials, is as concisely and thoroughly treated as the limits of the book will permit; it is, however, a department of engineering in which knowledge comes rather from experience and close observation than from much reading.

Part II, on the strength of materials, is based rather on empirical formulæ, than on the more modern German methods, which are equally correct and have the advantage of being logically deduced. and therefore more easily remembered, or deduced, by the student.

It is to be regretted that in the parts on framing, trussed bridges, and roofs, the applications of the newer, simpler and sufficiently correct methods of graphical statics, have not to a greater extent taken the place of the older and more involved analytical methods. Once learned, the graphical methods are never forgotten.

The space allotted to Railroads is too limited to do more than merely notice a few points in this vast field, and, strangely enough, some points of very little or no importance are quite as fully noticed as the more salient and important ones.

In Roads and Canals the work does not differ greatly from the older work of Mahan, for the very good reason that but few improvements have been made in the construction of either, since the publication of Mahan's Civil Engineering, which has served as a model for this work. M.

BAGGAGE CAR TRAFFIC. By Marshall M. Kirkman. Small 8vo, pp. 238. New York, *Railroad Gazette*, 1878.

No more striking proof of the intricacy involved in latter-day railway management could be adduced, than this book of 250 pages on what might seem a comparatively unimportant subject—the baggage car traffic on passenger trains.

The work is an exhaustive treatise, written in popular style, on the American system of handling baggage; the advantages of which were so strikingly exemplified during the Centennial; and also a comparison with foreign methods of doing the same work; and, strange as it may seem to the American railroader, a hint or two may be taken from our transatlantic cousins, upon whom the curse of hurry has not fallen so heavily as on us.

There is wit as well as wisdom in the book; witness the pen portraits of the train-boy and baggage-master, which much maligned individual is vindicated at the author's hands.

That no "'prentice hand" or theorizing amateur is writing, is proved by the absence of those ludicrous blunders so often perceived by experts in works of this class.

In short, it would pay every Railroad Company to buy a few copies of the book, and pass them around among its baggage-masters, who would gladly read what any one might have to say about their department, for among no body of men, outside of the army and navy, is the *esprit du corps* stronger than among railroad employees, and none are more jealous of their reputation for smartness in their own line. R.

THE ROADMASTER'S ASSISTANT AND SECTION-MASTER'S GUIDE. By Wm. S. Huntington. Small 8vo. New York, *Railroad Gazette*, 1878.

This is a book for which there has been a real need, since it is high time for the experience of practical railroad men in every department to be recorded for the benefit of their successors.

To one who has had opportunity of seeing the manner in which the permanent way of many of our railroads is maintained, and the class of men to whom the work is intrusted, it almost seems as though accidents should be the rule, instead of the exception.

Although the permanent way and works of many of our trunk lines and their connections have been brought to a high standard of perfection, these form but a small part of our great railway mileage.

Very many of the railroads in this country are struggling to make both ends meet and to pay fixed charges, compelled by competition to run heavy trains at high speeds, and with but little money with which to repair the destruction of tracks and bridges which they cause; and it is to the roadmasters and foremen of such railroads that this book will be particularly useful, since it shows them that it costs no more to do work right than wrong.

The chapters on Track-laying and Track repairs are particularly full of detail, and are, of course, the more valuable on that account; the cuts are clear, but there might be more of them.

The one great omission in this book is the lack of information regarding the nature, mode of handling, and manner of laying steel rails, which now form so important a part of railway economy.

The "sighting in" of ties, a method of doing which is described, has been very generally abandoned in the east, the ties being thrown down on the road-bed as left by the contractor, the rails being spiked at, and opposite, the joints, and then the whole track brought to surface and full-spiked, care being exercised lest the rails be bent or twisted by the material train.

The tables of elevations for outer rail of curves, and the bills of switch timbers, will be useful for reference; the index (so important in a work of this description) is all that can be desired, and the information generally is conveyed in so simple a style, that any man who can read at all should be able to understand it, which is the more necessary, as railroad foremen are not apt to be men of letters.

R.

LECTURES AT THE FRANKLIN INSTITUTE.

The lecture season for 1878–9 will begin on November 7th, 1878, and continue on Monday and Thursday evenings until February 24th, 1879.

The Institute now having increased facilities for illustrating the useful application of science, a larger number of lectures upon such subjects have been provided for, and among these are several which are now attracting a large amount of popular attention.

The gentlemen whose services have been secured for this season, and the subjects selected, are as follows:

PROF. E. J. HOUSTON, on Thursdays, beginning November 7th, 1878. Six lectures, on *Color*, *Lightning Rods*, *Electro-Magnetism*, *Telephone and Microphone*, *Relations of Light and Heat*, and *Conservation of Energy.*

DR. WM. H. GREENE, on Mondays, beginning November 11th, 1878. Eight lectures, on Organic Chemistry, or the *Chemistry of Carbon Compounds.*

PROF. ELIHU THOMSON, on Thursdays, beginning January 2d, 1879. Five lectures, on *Explosive Compounds*, *Mirrors and Lenses*, *The Spectroscope*, *Electric Lighting*, and *Electro-Chemistry.*

PROF. PERSIFOR FRAZER, JR., on Mondays, beginning January 6th, 1879. *An Introduction to Modern Chemistry and Physics*, in eight lectures.

MR. J. B. KNIGHT, on Thursday, February 6th, 1879. One lecture, on *Ice*.

MR. D. S. HOLMAN, on Thursdays, February 13th and 20th, 1879. Two lectures on *Motion and Life*, and *The Movement of Fluids in Plants and Animals, as seen with the Microscope.*

Franklin Institute.

HALL OF THE INSTITUTE, Oct. 16th, 1878.

The stated meeting was called to order at 8 o'clock P. M., Vice-President J. E. Mitchel in the chair.

There were present 104 members and 30 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting there were 5 persons elected members of the Institute, and the following donations made to the Library:

Geological report of Chesapeake and Ohio Railroad. By T. S. Ridgway.

Chesapeake and Ohio Railroad. Its advantages, etc., etc.

Letter of Prof. E. B. Andrews, on the Coal and Iron deposits in Perry county, Ohio.

Coal and Iron fields of Virginia and West Virginia. By D. T. Ansted.

Maps Nos. 6, 7, 9 and 10 of Grouped sections of Galla, Meigs, Morgan and Muskingum counties. By Andrews & Gilbert.

From C. H. Brownings, New York.

Maps (26) of Operations of the Union and Confederate Armies during 1863, '64 and '65.

Supplement to Official Gazette of United States Patent Office.

Specifications and Drawings of United States Patents for March 1878.

From the Patent Office, Washington.

Geological Survey of Pennsylvania, 1875–1877. Reports of progress. 3 K. N.; & Q.

From the Board of Commissioners, Harrisburg.

Annual Report of Light-House Board for year ending June 30, 1877. From the Secretary of the Treasury, Washington.

New View of the Weather Question. By J. P. Noyes. From the Author.

Bearing Piles. Compiled by R. Herring. From the Author.

Resistance des Materiaux. Par A. Morin. From the Author.

Electricity in Medicine and Surgery. From Western Electric Manufacturing Co.

Uniform Non-Local Time. A Memoir. By I. Fleming. From the Author.

Report on Widening of Delaware Avenue. From Clerk of Councils.

On a Dynamometer for Measuring Steam and Water-power.
Report on the Meteor of December 24th, 1873.
Report on the Metric System of Weights and Measures. April, 1878. From Engineers' Club of Philadelphia.

Alabama Coal and Navigation Company. Charter, August 22, 1871. From the Company.

Letter on the Tariff Question. By B. H. Moore. Philadelphia, 1878. From the Author.

Report to Board of Underwriters of New York. By C. H. Haswell, N. Y., 1877. From the Author.

Catalogues of the Central University. Richmond, Ky., 1876–77 and 1877–78. From the University.

Forty-second annual report of Directors of Ohio Mechanics' Institute. Cincinnati, 1870. From the Institute.

Eighteenth report to Council of City of Manchester on the working of the Public Free Library. 1869–70. From the Council.

Rules of Practice in the United States Patent Office. February and August, 1878. From E. Hiltebrand.

Harbor Bars. The Cause of their Formation. By H. F. Knapp. London, 1878. From the Author.

Report on Ventilation of Hall of Representatives. By R. Briggs, 1876. From the Author.

Eighth and Ninth reports upon the Improvement of the South Pass of the Mississippi River. By M. R. Brown. 1877 and 1878. From the Chief of Engineers, Washington.

Obituary Notice of J. C. Cresson. By F. Fraley. From the Author.

Annual report of Chief Engineer of Water Department of Wilmington, for 1877. From the Chief Engineer.

Iron and Steel Tests. By R. H. Thurston. From the Author.

Addenda to the report of Health Officer of Philadelphia, for 1877. From Health Officer.

Eighth report of President and Directors of the Lake Shore and Michigan Southern Railway Co., for 1877. From the Company.

Researches in Graphical Statistics. By Henry T. Eddy. New York, 1878. From the Author.

Fifty-eighth annual report of Managers of Apprentices' Library Company of Philadelphia. 1878. From the Company.

American Printer. By Thos. MacKellar. Philadelphia, 1878. From the Author.

Catalogue of Venezuelan Department at International Exhibition, 1876. From L. De la Cova, Consul for Venezuela, Philada.

Report on the Incrustation in Boilers. By Dr. R. Smith.

Report of Committee on Management of the Manchester Steam Users' Association. 1857, 1859, 1862 and 1877.

Report of Proceedings at Sixth annual meeting, held January 15, 1861.

Chief Engineer's annual report on the Periodical Indication and Inspection of Engines. 1877.

From Manchester Steam Users' Asso., Manchester, England.

The Secretary presented and described John G. Baker's Improvement in Drawing Boards, consisting of a metal ruler to be used in place of the ordinary T-square. This ruler is of the full length of the board, and carries a shaft supported by short studs on its upper face. At each end of the shaft are pinions, gearing into racks fastened to the ends of the board, thus ensuring parallelism in the movement of the ruler.

Also, Crook's Condenser, for steam engines, consisting of a nozzle inserted in the exhaust-pipe, and of such shape that when water is admitted, it is spread out in a thin sheet diagonally across the exhaust-pipe, thus facilitating the contact between the water and steam.

Mr. Howard Murphy described, and illustrated by means of the electric light, a simple photographic process for reproducing drawings. A strong, hard paper, such as ledger paper, is coated lightly by means of a camel's hair brush, with a sensitive solution, consisting of 1 part citrate of iron and ammonia, 1 part red prussiate of potash, and 10 parts clear water, and allowed to dry in the dark. If the drawing to be reproduced is on thick paper, a tracing must be made on tracing cloth or other semi-transparent material, and placed over and held smoothly and closely against the prepared paper, by a plate of glass, and the whole exposed to the sunlight for a few minutes. The prepared paper is then removed and laid in a bath of clear water for a few minutes, and then washed with a rose sprinkler, when the whole surface of the paper will be found of a deep blue color, except the lines of the drawing, which remain white.

Dr. Isaac Norris presented and described a new form of Microphone, devised by himself, in which he employs a cylinder of wood or other light material, about 3″ in diameter, and 4″ long, placed horizontally, over either end of which is stretched a membrane, forming two diaphragms. To the centre of one of the diaphragms is attached a silk thread, which passes over a small pulley, and has suspended at its end a metal cone with a carbon point. This cone is made hollow, in order that its weight may be adjusted by adding small shot. Directly under the cone is placed a carbon rod, adjustable perpendicularly, so as to secure a very delicate contact. The electric circuit is completed through it, the cone, and a Bell telephone. This instrument is very sensitive to sound, and with a stethoscope, connected with the cylinder by means of a flexible tube, was designed to aid in the study of the sounds of the heart and lungs.

Mr. F. T. Freeland presented and described a machine, designed and constructed by himself, for playing the game of tit-tat-to. The machine is so designed that the move made by the person playing against it, determines that next made by the machine, the latter being accomplished by the simple movement back and forward of two levers, and the most skilful player is unable to win any one of the vast number of variations of which this simple game is susceptible.

Mr. Robert Briggs gave an interesting description of his recent visit to the Paris Exposition, and drew some unfavorable comparisons between its buildings and general arrangements, and those of our Centennial Exhibition.

On motion, the meeting adjourned.

J. B. Knight, *Secretary.*

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

Vol. CVI. DECEMBER, 1878. No. 6.

The Franklin Institute is not responsible, as a body, for the statements and opinions advanced by contributors to the Journal.

THE CHEMICAL COMPOSITION AND PHYSICAL PROPERTIES OF STEEL RAILS.[1]

By C. B. Dudley, Ph. D., Chemist, Penna. R. R. Co.

In the spring of 1877, the Pennsylvania Railroad Company became so dissatisfied with the average life and wear of the steel rails it was then able to procure, that it determined to make an investigation into the chemical composition and physical properties of steel rails, with a view, first, to answering the question why one steel rail has to be removed from the track after, perhaps, 8 months' service, while another lasts 10 years; and, secondly, if this investigation succeeded in throwing light on this important subject, to use this information in securing better rails in the future. The results of that investigation are contained in the following report. In presenting this report to the Institute of Mining Engineers, which I am permitted to do by the kindness of the officers of the Pennsylvania Railroad Company, it has been thought best to retain the form and style in which the report was written. For although the report was originally written for the officers of the Pennsylvania Railroad Company, and, consequently, the discussion of details made a little more full than if it had been written as a scientific paper, yet this very fullness of detail may not be amiss in a field where knowledge is so urgently needed.

---

[1] A paper read before the October (1878), meeting of the American Institute of Mining Engineers.

REPORT.

THEO. N. ELY, ESQ., *Supt. Motive Power*, *Penna. R. R. Co.*

Dear Sir:—I have finished the examination of the subject of steel rails in connection with their chemical constitution, physical properties, and wear, which has occupied my attention and study, more or less constantly, for six months past, and beg leave to present thereon the following report:

The question which led to, and has followed in all its details, the investigation embraced in this report, is: How shall the Pennsylvania Railroad Company obtain steel rails which shall give a satisfactory wear and be uniform in quality?

In order to understand the attempt which has been made to answer this question, it will be necessary to state a few preliminary principles. It seems to be agreed among metallurgists, that the quality of a piece of steel depends upon two sets of circumstances: 1st, upon its chemical constitution, and 2d, upon the treatment which the metal receives either during or after its manufacture. In other words, a piece of steel of certain chemical constitution and treatment will have certain physical qualities of strength, elasticity, ductility, power to resist wear, etc.; or again, a different chemical constitution and treatment will give a piece of steel which will differ in one or more of these respects from the first; the former being possibly more valuable for rails, the latter for cutting-tools.

Now it is to be confessed at the outset, that our knowledge of these two sets of circumstances, viz., the chemical constitution and treatment necessary to secure such a piece of steel as is desired, is far from being all that could be wished for. Nevertheless, some things are known, and the work which is described below is an attempt to add to our knowledge in this respect, with regard to steel rails.

Now inasmuch as all our steel rails are made at present by the Bessemer or Pneumatic process, and inasmuch as the conditions of successful working of this process are pretty well understood, it is assumed that the *treatment* which the steel receives during manufacture is constant or always alike. That this is an actual fact in practice, is probably not true. The carelessness of workmen, and the want of proper appliances, may at times cause more or less variation in the treatment which the successive "blows" or heats in the Bessemer converter receive. These variations are, however, undoubtedly small, and where care is taken, and the Bessemer process given its full chance, the want of uniformity of product, so far as that uniformity depends upon treatment or method of manufacture, should be very small. I would not be understood as saying, however, that I think the Bessemer process has reached its full development, or is incapable of further improvement. The difficulty of obtaining solid ingots, whether it is better to use the bottom or top cast, whether the slag is all separated before casting, at what temperature the rail should go through the rolls, and especially the last pass, and how to get this temperature, are questions still awaiting solution, and I think it undoubted, that to one or more, or possibly all combined, of these uncertainties are due some of the anomalies which are often met with in steel.

Nevertheless, assuming, as has already been stated, that the Bessemer process, as at present understood and worked, is capable, in careful hands, of turning out a moderately uniform product, so far as that uniformity depends upon *treatment* or method of manufacture—which is undoubtedly the case—the question how to obtain a good rail becomes one as to the chemical composition of the steel, and this is the part of the problem to which I have devoted some labor and study. We are fortunately, however, not entirely dependent for uniformity of product, so far as that uniformity depends upon treatment or method of manufacture, upon the uniformity with which the rail manufacturers work the Bessemer process. Just here comes in the sphere for appropriate physical tests and inspection. For example, it seems clear to me that if a "blow" or heat in the Bessemer converter is badly treated at any point during the manufacture, so that the steel is spoiled, appropriate physical tests and inspection will reveal this fact, and thus enable us to protect ourselves by rejecting that "blow." So that the question with which we started, viz., How shall the Pennsylvania Railroad Company obtain steel rails which shall give satisfactory wear and be uniform in quality? seems to be resolved into two others, viz., (1) With the present known metallurgical methods in the Bessemer process, what chemical composition shall the Pennsylvania Railroad Company prescribe for its rails? and (2) What physical tests and inspection shall it apply to secure uniformity of product? What follows is an attempt to answer these questions.

I.—As to Chemical Composition.

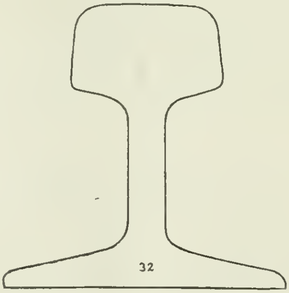
It is well known that there are six impurities which exist in nearly all iron and steel in greater or less amount, which are known to have important influences upon its quality, even in small quantities. These are carbon, phosphorus, silicon, manganese, sulphur and copper, and when we speak of the chemical composition of steel, we mean the amount of these various impurities which the steel contains. Steel, and especially pig iron contain other impurities, such as titanium, cobalt, nickel, arsenic, etc., but these are commonly disregarded in analysis because their amount is usually very small, and some of them are not known to have any influence upon the quality of the metal. A discussion as to the influence of these various impurities upon the quality of steel, will follow later. It is sufficient here to say, that almost the only effect that sulphur and copper are known to have on steel, is to render it what is technically known as "red short," that is, if a steel rail has too much sulphur and copper in it, it crushes in the rolls or flies to pieces, during manufacture. I am unable to find, anywhere, that sulphur and copper are said to have a deleterious effect on the wear or durability of a rail, and indeed, some metallurgists claim that they are advantageous in this respect. I have, therefore, not determined the sulphur or copper in the analyses given below, and would not recommend to prescribe any specifications in regard to them. We can safely trust the rail manufacturers not to give us rails containing too much sulphur and copper.

As to the other four impurities, the question now arises, how much of these various substances ought a good steel rail to contain? In order to answer this question, twenty-five pieces of steel rail have been carefully analyzed for carbon, phosphorus, silicon and manganese. The borings for analysis were taken out of the physical test pieces described below. The chemical work was all done in duplicate. The carbon was determined by combustion, working upon 7 grams, dissolving out the carbon with solution of the double chloride of copper and ammonium, and burning with chromate of lead. The phosphorus was determined by the molybdate of ammonium method, working upon 3 grams, and dissolving the steel in aqua regia. The manganese was determined by the bromine method, separating the iron as basic acetate, and using acetate of soda as the precipitant. The silicon was determined in the usual way, working upon 10 grams, and dissolving in hydrochloric acid. The twenty-five samples of steel rail which were analyzed, have all been in actual service; some of them have broken in service, some have crushed in service, some have worn badly with short service, and some have endured long and hard service. The brands of steel represented in the series, are: Penn. steel, Cambria steel, Lackawanna Iron and Coal Co.'s steel, Cammel steel, Mersey steel, Ebbw Vale steel, and John Brown steel. It was thought that the series would represent, as fairly as a series of twenty-five samples could do, the actual results of good and bad service of rails on the Penna. R. R. Moreover, the samples were taken from all parts of the road, thereby rendering inoperative the influence of local causes upon the life and wear of the rails. If now the chemical composition of the good rails should show uniformity within narrow limits, while the chemical composition of the bad rails should likewise show uniformity; and if these uniformities of chemical composition in the good rails and bad rails should differ from each other, it would seem to be fair to conclude that the composition of the bad rails should be avoided, while that of the good rails should be adopted. That the good rails show a moderate uniformity of chemical composition, different from that of the bad rails, will be evident, I think, from an inspection of the analyses which follow.

One or two things more ought to be mentioned. In order to measure the value of a rail as to whether good or bad, the approximate tonnage which has passed over each of these pieces of rail has been computed; it being of course evident to all that the burden which a rail has sustained, even though approximately determined, is a much more accurate measure of its value than time of service. Again, position in a track, whether on a curve or on a straight line, and also whether subject to high speed or not, obviously have an influence upon the durability of a rail, and attention has been given to these points in estimating the value of a rail. It will be noticed in the tables which follow that the principle of measuring the value of a rail by the tonnage which has passed over it has not been strictly followed. The rails have been divided in the tables into two classes on this principle, viz.: *Those which crushed or broke in service* and *those which did not crush or break in service.* The former are regarded as bad rails and the latter as good rails. This principle of division brings among the bad rails four whose tonnage is higher than the lowest tonnage of any rail among the good ones. But in view of the liability to accident which a broken or crushed rail may occasion, I think no one will claim that a rail which has broken or crushed in service should be classed among good rails, even though its tonnage may entitle it to be so rated.

Finally, as a means of determining whether good rails differed from bad rails in physical qualities, such as tensile strength, ductility, etc., and if it was found that they did so differ, as a means of enabling us to specify what physical tests the steel for our rails ought to stand, careful physical tests have been made of every piece of steel analyzed except two, the samples sent for analysis of these two being so small as to prevent physical tests being made. The physical tests were made on Prof. Thurston's Torsional Testing Machine, as being the best means of determining the largest number of physical qualities at a single test. A copy of the diagrams obtained in making these tests accompanies this report, and will be referred to later.

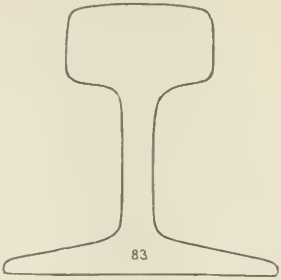
The history of each piece of rail analyzed, together with an outline sketch of the piece (one-third size) as it appeared when removed from the track, the tonnage, chemical analysis, and results of physical tests are given in order below. Following these is a tabulated statement of these results, and the conclusion drawn from them.



No. 32—Broken near Edgar Thomsen Steel Works, first time train passed over it. Tonnage, 0,000,000 *tons.*

CHEMICAL ANALYSIS.	
Carbon	0·359
Phosphorus	·156
Manganese	·505
Silicon	·035
Total Hardeners	1·055
" in P. units	39·4

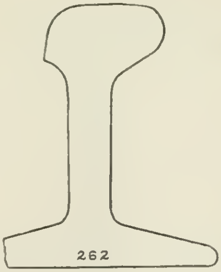
PHYSICAL TESTS.	
Angle of Torsion	111°
Moment of Torsion	333
Tensile Strength at Rupture	78,255
" " " Elastic Limit	30,550
Percentage of Elongation	16·898
Proportional Ultimate Resilience	29·80



No. 83.—*In service from June*, 1875, *to September*, 1876; *sixteen months. Was in south track on* 9° *curve, just east of Columbia Tunnel. Broke in service. Tonnage*, 10,027,131 *tons.*

CHEMICAL ANALYSIS.	
Carbon	0·323
Phosphorus	·135
Manganese	·522
Silicon	·035
Total Hardeners	1·015
" in P. units	36·4

PHYSICAL TESTS.	
Angle of Torsion	106°
Moment of Torsion	340
Tensile Strength at Rupture	79,900
" " " Elastic Limit	33,135
Percentage of Elongation	15·509
Proportional Ultimate Resilience	28·60

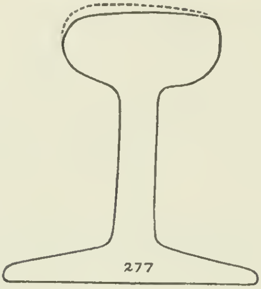


No. 262.—*In service from October*, 1868, *to November*, 1876; *eight years, one month. Was in south track on* 9° *curve, just west of Valley Creek Bridge. Tonnage*, 44,636,201 *tons.*

CHEMICAL ANALYSIS.	
Carbon	0·337
Phosphorus	·056
Manganese	·374
Silicon	·056
Total Hardeners	·823
" in P. units	27·1

PHYSICAL TESTS.

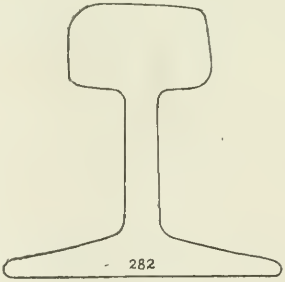
No Physical Tests were made, because of smallness of piece of rail sent.



No. 277.—*In service from September*, 1872, *to December*, 1876; *four years, three months. Was in south track on tangent, about midway between South Elizabeth and Linden. Broke in service. Tonnage*, 16,600,728 *tons.*

Chemical Analysis.	
Carbon	0·573
Phosphorus	·075
Manganese	·853
Silicon	·182
Total Hardeners	1·688
" in P. units	52·9

Physical Tests.	
Angle of Torsion	101°
Moment of Torsion	433
Tensile Strength at Rupture	101,755
" " " Elastic Limit	43,005
Percentage of Elongation	14·169
Proportional Ultimate Resilience	36·81

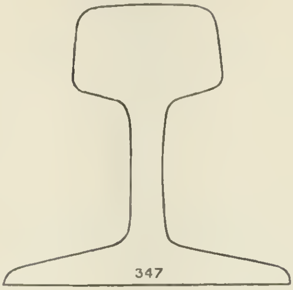


No. 282.—*In service from August*, 1875, *to January*, 1877; *one year, five months. Was in single track near Marr's Run Station, on N. C. R. W. Broke in service. On tangent. Tonnage*, 4,535,318 *tons.*

Chemical Analysis.	
Carbon	0·354
Phosphorus	·132
Manganese	·552
Silicon	·050
Total Hardeners	1·088
" in P. units	38·5

Physical Tests.

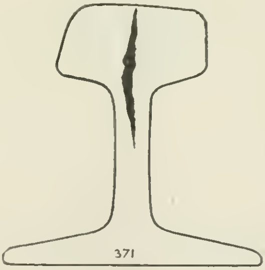
No Physical Tests were made, because of smallness of piece of rail sent.



No. 347.—*Broke after five days' service on New York Division. Tonnage,* 0,000,000 *tons.*

CHEMICAL ANALYSIS.	
Carbon	0·387
Phosphorus	·056
Manganese	·670
Silicon	·035
Total Hardeners	1·148
" in P. units	36·6

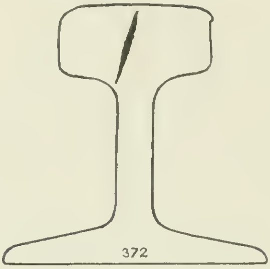
PHYSICAL TESTS.	
Angle of Torsion	67°
Moment of Torsion	306
Tensile Strength at Rupture	71,910
" " " Elastic Limit	30,550
Percentage of Elongation	6·467
Proportional Ultimate Resilience	16·65



No. 371.—*In service from July,* 1876, *to March,* 1877; *eight months. Was in single track, on Tyrone and Clearfield Division, south of Mount Pleasant. On curve* 16°. *Tonnage,* 2,741,056 *tons.*

CHEMICAL ANALYSIS.	
Carbon	0·386
Phosphorus	·127
Manganese	·380
Silicon	·053
Total Hardeners	·946
" in P. units	35·8

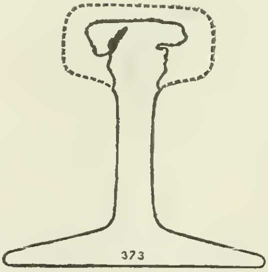
PHYSICAL TESTS.	
Angle of Torsion	85°
Moment of Torsion	342
Tensile Strength at Rupture	80,370
" " " Elastic Limit	47,000
Percentage of Elongation	10·223
Proportional Ultimate Resilience	24·68



No. 372.—*In service from July*, 1876, *to March*, 1877; *eight months. Was in single track on* 17° *curve, Tyrone and Clearfield Division, south of Mount Pleasant. Tonnage*, 2,741,056 *tons.*

Chemical Analysis.	
Carbon	0·416
Phosphorus	·155
Manganese	·460
Silicon	·034
Total Hardeners	1·065
" in P. units	40·3

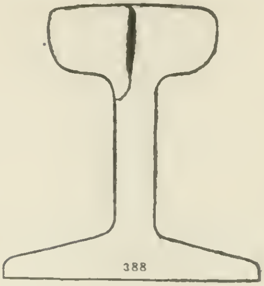
Physical Tests.	
Angle of Torsion	102°
Moment of Torsion	346
Tensile Strength at Rupture	81,310
" " " Elastic Limit	30,550
Percentage of Elongation	14·433
Proportional Ultimate Resilience	29·26



No. 373.—*In service from July*, 1876, *to March*, 1877; *eight months. Was in single track on* 20° *curve, Tyrone and Clearfield Division, south of Mount Pleasant. Tonnage*, 2,741,056 *tons.*

Chemical Analysis.	
Carbon	0·300
Phosphorus	·138
Manganese	·412
Silicon	·024
Total Hardeners	·874
" in P. units	33·2

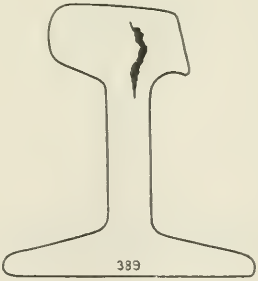
Physical Tests.	
Angle of Torsion	102°
Moment of Torsion	281
Tensile Strength at Rupture	66,035
" " " Elastic Limit	25,850
Percentage of Elongation	14·433
Proportional Ultimate Resilience	23·06



No. 388.—*In service from March,* 1867, *to March,* 1877; *ten years. Was in north track on a tangent near Ardmore Station. Tonnage,* 37,005,142 *tons.*

Chemical Analysis.	
Carbon	0·303
Phosphorus	·166
Manganese	·316
Silicon	·032
Total Hardeners	·817
" in P. units	34·6

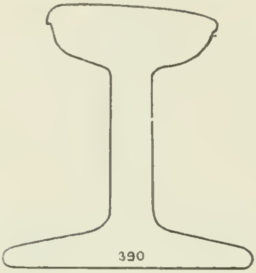
Physical Tests.	
Angle of Torsion	120°
Moment of Torsion	322
Tensile Strength at Rupture	75,670
" " " Elastic Limit	31,725
Percentage of Elongation	19·514
Proportional Ultimate Resilience	31·21



No. 389.—*In service from March,* 1872, *to April,* 1877; *five years, one month. Was on south track on a curve, one mile west of Huntingdon. Tonnage,* 34,333,639 *tons.*

Chemical Analysis.	
Carbon	0·343
Phosphorus	·127
Manganese	·670
Silicon	·036
Total Hardeners	1·176
" in P. units	39·3

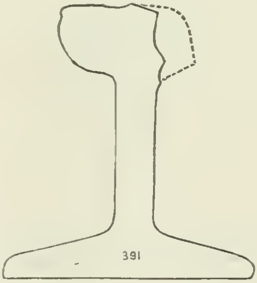
Physical Tests.	
Angle of Torsion	121°
Moment of Torsion	320
Tensile Strength at Rupture	75,200
" " " Elastic Limit	30,550
Percentage of Elongation	19·813
Proportional Ultimate Resilience	31·02



No. 390.—*In service from March*, 1868, *to March*, 1877; *nine years. Was in south track on* 2° *curve, on eastern slope of mountain. Pittsburg Division. Tonnage,* 47,332,411 *tons.*

CHEMICAL ANALYSIS.	
Carbon	0·291
Phosphorus	·057
Manganese	·354
Silicon	·068
Total Hardeners	·770
" in P. units	25·9

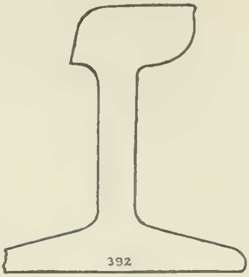
PHYSICAL TESTS.	
Angle of Torsion	126°
Moment of Torsion	302
Tensile Strength at Rupture	70,970
" " " Elastic Limit	32,900
Percentage of Elongation	21·337
Proportional Ultimate Resilience	31·95



No. 391.—*In service from June*, 1871, *to April*, 1877; *five years, ten months. Was in south track on* 4½° *curve*, 1700 *feet west of M. P.*, 84 *from Pittsburg. Tonnage,* 30,873,173 *tons.*

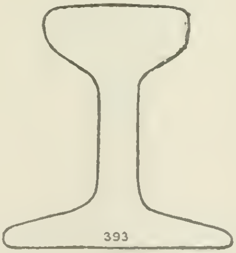
CHEMICAL ANALYSIS.	
Carbon	0·294
Phosphorus	·181
Manganese	·354
Silicon	·020
Total Hardeners	·849
" in P. units	36·0

PHYSICAL TESTS.	
Angle of Torsion	117°
Moment of Torsion	333
Tensile Strength at Rupture	78,255
" " " Elastic Limit	33,605
Percentage of Elongation	18·626
Proportional Ultimate Resilience	32·42



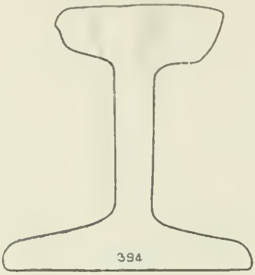
No. 392.—*In service from April,* 1871, *to April,* 1877; *six years. Was in south track on* 4° *curve,* 800 *feet east of M. P.,* 106 *from Pittsburg. Tonnage,* 32,957,247 *tons.*

CHEMICAL ANALYSIS.		PHYSICAL TESTS.	
Carbon	0·231	Angle of Torsion	151°
Phosphorus	·087	Moment of Torsion	294
Manganese	·364	Tensile Strength at Rupture	69,090
Silicon	·047	" " " Elastic Limit	30,550
Total Hardeners	·729	Percentage of Elongation	29·548
" in P. units	26·0	Proportional Ultimate Resilience	37·24



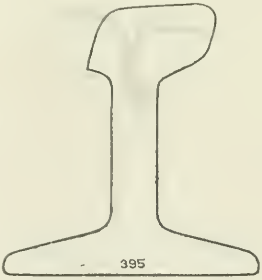
No. 393.—*In service from July,* 1867, *to July,* 1873, *in north track at M. P.,* 115 *from Philadelphia; then from July,* 1873, *to April,* 1877, *in No.* 1, *south siding, Mifflin Yard. Total service, nine years, ten months. Tonnage,* 17,083,416 *tons.*

CHEMICAL ANALYSIS.		PHYSICAL TESTS.	
Carbon	0·219	Angle of Torsion	217°
Phosphorus	·065	Moment of Torsion	285
Manganese	·272	Tensile Strength at Rupture	66,975
Silicon	·028	" " " Elastic Limit	28,200
Total Hardeners	·584	Percentage of Elongation	54·944
" in P. units	20·6	Proportional Ultimate Resilience	49·63



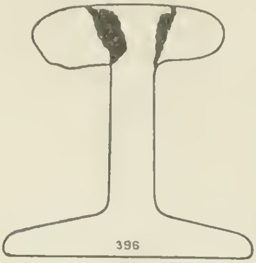
No. 394.—*In service from April*, 1871, *to April*, 1877; *six years. Was in south track on* 2° *curve*, 2600 *feet west of M. P.*, 27 *from Pittsburg. Tonnage*, 25,043,350 *tons.*

Chemical Analysis.		Physical Tests.	
Carbon	0·286	Angle of Torsion	149°
Phosphorus	·083	Moment of Torsion	322
Manganese	·418	Tensile Strength at Rupture	75,670
Silicon	·023	“ “ “ Elastic Limit	45,825
Total Hardeners	·810	Percentage of Elongation	28·857
“ in P. units	27·3	Proportional Ultimate Resilience	41·65



No. 395.—*In service from September*, 1872, *to March*, 1877; *four years, seven months. Was in south track on* 4° *curve*, 1200 *feet west of M. P.*, 59 *from Pittsburg. Tonnage*, 24,606,889 *tons.*

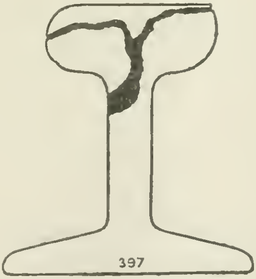
Chemical Analysis.		Physical Tests.	
Carbon	0·353	Angle of Torsion	134°
Phosphorus	·103	Moment of Torsion	338
Manganese	·576	Tensile Strength at Rupture	79,430
Silicon	·059	“ “ “ Elastic Limit	32,900
Total Hardeners	1·091	Percentage of Elongation	23·860
“ in P. units	36·5	Proportional Ultimate Resilience	37·49



No. 396.—*In service from January,* 1874, *to January,* 1877; *three years. Was in Subdivision* 11, *Pittsburg Division; the records of which were destroyed by the riots. Tonnage,* 13,683,266 *tons.*

CHEMICAL ANALYSIS.	
Carbon	0·350
Phosphorus	·134
Manganese	·626
Silicon	·058
Total Hardeners	1·168
" in P. units	40·5

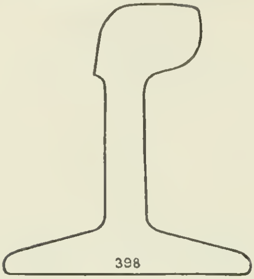
PHYSICAL TESTS.	
Angle of Torsion	105°
Moment of Torsion	342
Tensile Strength at Rupture	80,370
" " " Elastic Limit	36,425
Percentage of Elongation	15·237
Proportional Ultimate Resilience	29·06



No. 397.—*In service from July,* 1872, *to May,* 1877; *four years, seven months. Was in south track on tangent* 650 *feet west of M. P.,* 11 *from Pittsburg. Tonnage,* 21,935,613 *tons.*

CHEMICAL ANALYSIS.	
Carbon	0·365
Phosphorus	·130
Manganese	·458
Silicon	·020
Total Hardeners	·973
" in P. units	35·3

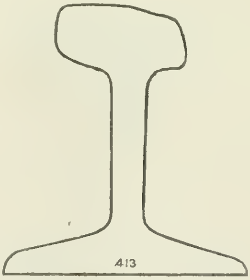
PHYSICAL TESTS.	
Angle of Torsion	82°
Moment of Torsion	260
Tensile Strength at Rupture	61,100
" " " Elastic Limit	25,850
Percentage of Elongation	9·545
Proportional Ultimate Resilience	16·86



No. 398.—*In service from January,* 1871, *to March,* 1877; *six years, two months. Was in north track on* 4° *curve,* 120 *feet west of M. P.,* 12 *from Pittsburg. Tonnage,* 27,296,043 *tons.*

Chemical Analysis.	
Carbon	0·225
Phosphorus	·111
Manganese	·318
Silicon	·016
Total Hardeners	·670
" in P. units	25·8

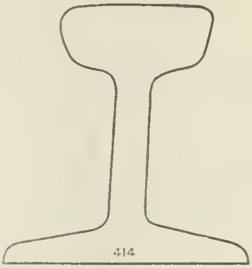
Physical Tests.	
Angle of Torsion	130°
Moment of Torsion,	282
Tensile Strength at Rupture	66,270
" " " Elastic Limit	27,025
Percentage of Elongation	22·586
Proportional Ultimate Resilience	28·93



No. 413.—*In service from June,* 1867, *to October,* 1876; *nine years, four months. Was in single track on* 8° 40′ *curve, at west end of Schuylkill Bridge, Del. Ex. R. R. Tonnage,* 36,901,508 *tons.*

Chemical Analysis.	
Carbon	0·233
Phosphorus	·041
Manganese	·208
Silicon	·074
Total Hardeners	·556
" in P. units	19·7

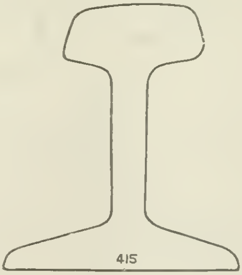
Physical Tests.	
Angle of Torsion	175°
Moment of Torsion	280
Tensile Strength at Rupture	65,800
" " " Elastic Limit	28,435
Percentage of Elongation	38·239
Proportional Ultimate Resilience	39·49



No. 414.—*In service from May* 1867, *to November,* 1876; *nine years, six months. Was in west bound freight track on tangent, east of 35th Street Bridge, West Philadelphia. Tonnage,* 34,839,538 *tons.*

Chemical Analysis.	
Carbon	0·309
Phosphorus	·058
Manganese	·326
Silicon	·030
Total Hardeners	·723
“ in P. units	24·1

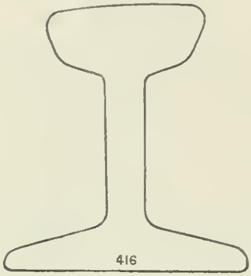
Physical Tests.	
Angle of Torsion	148°
Moment of Torsion	292
Tensile Strength at Rupture	68,620
“ “ “ Elastic Limit	27,730
Percentage of Elongation	28·514
Proportional Ultimate Resilience	35·86



No. 415.—*In service from April,* 1867, *to July,* 1876; *nine years, three months. Was in south track, four years on* 2° *curve, and five years on tangent, near Marysville, Middle Division. Tonnage,* 48,037,879 *tons.*

Chemical Analysis.	
Carbon	0·336
Phosphorus	·079
Manganese	·458
Silicon	·061
Total Hardeners	·934
“ in P. units	31·3

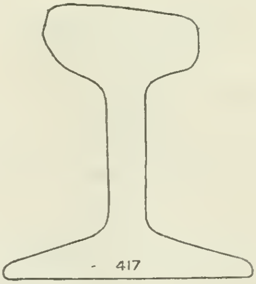
Physical Tests.	
Angle of Torsion	137°
Moment of Torsion	321
Tensile Strength at Rupture	75,435
“ “ “ Elastic Limit	31,725
Percentage of Elongation	24·833
Proportional Ultimate Resilience	36·75



No. 416.—*In service from June*, 1868, *to September*, 1876; *eight years, three months. Was in south track on tangent opposite Harrisburg Freight Warehouse. Tonnage*, 47,354,754 *tons.*

Chemical Analysis.	
Carbon	0·283
Phosphorus	·114
Manganese	·334
Silicon	·030
Total Hardeners	·761
" in P. units	29·0

Physical Tests.	
Angle of Torsion	127°
Moment of Torsion	289
Tensile Strength at Rupture	67,915
" " " Elastic Limit	28,200
Percentage of Elongation	21·647
Proportional Ultimate Resilience	29·87



No. 417.—*In service from December*, 1867, *to July*, 1876; *nine years, six months. Was in north track on* 4½° *curve, at Jackstown Water Station, Middle Division. Tonnage*, 34,108,667 *tons.*

Chemical Analysis.	
Carbon	0·345
Phosphorus	·075
Manganese	·426
Silicon	·041
Total Hardeners	·887
" in P. units	29·6

Physical Tests.	
Angle of Torsion	124°
Moment of Torsion	312
Tensile Strength at Rupture	73,320
" " " Elastic Limit	30,080
Percentage of Elongation	20·722
Proportional Ultimate Resilience	31·77

TABLE I.

Showing Tonnage, Location and Results of Chemical Analysis of Twenty-five Samples of Steel Rail.

Rail No.	Tonnage.	Location.	C.	Phos.	Man.	Si.	Total.	Tot. in Phos. Units.
415	48,037,879	2° C. and Tangent	0·336	0·079	0·458	0·061	0·934	31·3
416	47,354.754	Tangent.	0·283	0·114	0·334	0 030	0·761	29·0
390	47,332,411	2° Curve.	0·291	0 057	0·354	0·068	0·770	25·9
262	44,636,201	9° "	0·337	0·056	0·374	0·056	0·823	27·1
413	36,901,508	8$\frac{2}{3}$° "	0·233	0·041	0·208	0·074	0·556	19·7
414	34,839.538	Tangent.	0 309	0·058	0·326	0·030	0·723	24·1
417	34,108,667	4½° Curve.	0·345	0·075	0·426	0·041	0·887	29·6
392	32,957,247	4° Curve.	0·231	0·087	0·364	0·047	0·729	26·0
398	27,296,043	4° "	0 225	0·111	0·318	0·016	0·670	25·8
394	25,043,350	2° "	0·286	0·083	0·418	0·023	0·810	27·3
395	24,606,889	4° "	0·353	0·103	0·576	0·059	1·091	36·5
393	17,083,416	Tangent.	0·219	0·065	0·272	0·028	0·584	20·6
388	37,005,142	Tangent.	0·303	0·166	0·316	0·032	0·817	34·6
389	34,333,639	Curve.	0 343	0·127	0·670	0·036	1·176	39·3
391	30,873.173	4½° Curve.	0 294	0·181	0·354	0·020	0·849	36·0
397	21,935,613	Tangent.	0·365	0·130	0·458	0·020	0·973	35·3
277	16,600,728	"	0·573	0·075	0·853	0·182	1·688	52·9
396	13,683,266	Unknown.	0·350	0·134	0·626	0·058	1·168	40·5
83	10,027,131	9° Curve.	0·323	0·135	0·522	0·035	1·015	36·4
282	4,535,318	Tangent.	0 354	0·132	0·552	0·050	1·088	38·5
371	2,741,056	16° Curve.	0·386	0·127	0·380	0·053	0·946	35·8
372	2,741,056	17° "	0·416	0·155	0·460	0·034	1·065	40·3
373	2.741,056	20° "	0·300	0·138	0·412	0·024	0·874	33·2
347	5 Days' Service.	Unknown.	0·387	0·056	0·670	0·035	1·148	33·6
32	Broke 1st Train.	"	0·359	0·156	0·505	0·035	1·055	39·4

TABLE II.

Showing Tonnage, Location and Results of Physical Tests of Twenty-five Samples of Steel Rail.

Rail No.	Tonnage.	Location.	Angle of Torsion.	Moment of Torsion.	Tensile Strength.	Tensile Strength at Elastic Limit.	Elongation.	Ultimate Resilience.
415	48,037,879	2° C. and Tangent	137°	321	75,435	31,725	0·248	36·75
416	47,354,754	Tangent.	127°	289	67,915	28,200	0·216	29·87
390	47,332,411	2° Curve.	126°	302	70,970	32,900	0·213	31·95
262	44,636,201	9° "	No	tests	made	of this	rail.	
413	36,901,508	8⅔° "	175°	280	65,800	28,435	0·382	39·49
414	34,839,538	Tangent.	148°	292	68,620	27,730	0·285	35·86
417	34,108,667	4½° Curve.	124°	312	73,320	30.080	0·207	31·77
392	32,957,247	4° "	151°	294	69,090	30,550	0·295	37·24
398	27,296,043	4° "	130°	282	66,270	27,025	0·226	28·93
394	25,043,350	2° "	149°	322	75,670	45,825	0·288	41·65
395	24,606,889	4° "	134°	338	79,430	32,900	0·239	37·49
393	17,083,416	Tangent.	217°	285	66,975	28,200	0·549	49·63
388	37,005,142	"	120°	322	75,670	31,725	0·195	31·21
389	34,333,639	Curve.	121°	320	75,200	30,550	0·198	31·02
391	30,873,173	4½° Curve.	136°	333	78,255	33,605	0·186	32·42
397	21,935,613	Tangent.	82°	260	61,100	25,850	0·095	16·86
277	16,600,728	"	101°	433	101,755	43,005	0·142	36·81
396	13,683,266	Unknown.	105°	342	80,370	36,425	0·152	29·06
83	10,027,131	9° Curve.	106°	340	79,900	33,135	0·155	28·60
282	4,535,318	Tangent.	No	tests	made	of this	rail.	
371	2,741,056	16° Curve.	85°	342	80,370	47,000	0·102	24·68
372	2,741,056	17° "	102°	346	81,310	30,550	0·144	29·26
273	2.741,056	20° "	102°	281	66,035	25,850	0·144	23·06
347	5 Days' Service.	Unknown.	67°	306	71,910	30,550	0·065	16·65
32	Broke 1st Train.	"	111°	333	78,255	30,550	0·169	29·80

TABLE III.

Showing Tonnage, Location, Results of Chemical Analysis, and Physical Tests of Twenty-five Samples of Steel Rail.

Rail No.	Tonnage. Million Tons.	Location.	C.	Phos.	Man.	Si.	Total in Phos. Units.	Tensile Strength. 1000 lbs.	Elastic Limit. 1000 lbs.	Percent. of Elongation.	Ultimate Resilience.	
415	48	2° C. and Tangent	·336	·079	·458	·061	31·3	75	32	25	37	Did not Break or Crush in Service.
416	47	Tangent.	·283	·114	·334	·030	29·0	68	28	22	30	
390	47	2° Curve.	·291	·057	·354	·068	25·9	71	33	21	32	
262	45	9° "	·337	·056	·374	·056	27·1	No	tests	made		
413	37	$8\frac{2}{3}$° "	·233	·041	·208	·074	19·7	66	28	38	39	
414	35	Tangent.	·309	·058	·326	·030	24·1	69	28	28	36	
417	34	4½° Curve.	·345	·075	·426	·041	29·6	73	30	21	32	
392	33	4° "	·231	·087	·364	·047	26·0	69	30	29	37	
398	27	4° "	·225	·111	·318	·016	25·8	66	27	23	29	
394	25	2° "	·286	·083	·418	·023	27·3	75	46	29	42	
395	25	4° "	·353	·103	·576	·059	36·5	79	33	24	37	
393	17	Tangent.	·219	·065	·272	·028	20·6	67	28	55	50	
388	37	Tangent.	·303	·166	·316	·032	34·6	76	32	19	31	Broke or Crushed in Service.
389	34	Curve.	·343	·127	·670	·036	39·3	75	30	20	31	
391	31	4½° Curve.	·294	·181	·354	·020	36·0	78	31	19	32	
397	22	Tangent.	·365	·130	·458	·020	35·3	61	26	9	17	
277	17	"	·573	·075	·853	·182	52·9	101	43	14	37	
396	14	Unknown.	·350	·134	·626	·058	40·5	80	36	15	29	
83	10	9° Curve.	·323	·135	·522	·035	36·4	80	33	15	29	
282	5	Tangent.	·354	·132	·552	·050	38·5	No	tests	made		
371	3	16° Curve.	·386	·127	·380	·053	35·8	80	47	10	25	
372	3	17° "	·416	·155	·460	·034	40·3	81	30	14	29	
373	3	20° "	·300	·138	·412	·024	33·2	66	26	14	23	
347	0	Unknown.	·387	·056	·670	·035	33·6	72	30	6	17	
32	0	"	·359	·156	·505	·035	39·4	78	30	17	30	

Table III contains a condensed statement of the results of Chemical Analysis and Physical Tests, together with the tonnage and location of the 25 samples of rails analyzed. As has been previously mentioned, the rails analyzed have been divided into two groups. Those which *did not break or crush in service* have been placed first in Table III, and in the other tables of this report, and embrace the first 12 samples, down to and including No. 393. The remaining 13 rails either *crushed or broke in service.* To a study of this statement, attention is now directed.

But first a brief discussion as to the influence of the various substances affecting the quality of steel, viz., carbon, phosphorus, silicon and manganese, upon the metal, will perhaps be in order. And here, at the start, I should like to frankly confess that our knowledge of the influence of these substances upon each other, and upon steel, is far from being as complete as we could wish. How thoroughly this lack of knowledge is recognized, may be inferred from the fact that one of the important duties with which the U. S. Test Commission, organized some two years ago, was charged, was this very point of the influence of the various impurities which exist in iron and steel upon the metal and upon each other in the metal. In view of this lack of knowledge, we can only, as it seems to me, apply what is already known, and, at the same time, study the results which we ourselves have obtained, with a view of deriving from them, as far as possible, the information they are calculated to teach. What, then, is the influence, so far as we know, of phosphorus, silicon, carbon, and manganese, upon steel for rails? Phosphorus, even in very small quantities, hardens steel and makes it brittle, and, at the same time, seems to render it especially liable to fracture from percussion or blows. Silicon hardens steel and renders it brittle, but in less degree than phosphorus. Carbon hardens steel and makes it brittle, and, at the same time, up to certain limits, adds to its strength, but seems to diminish its ductility or percentage of elongation, almost directly in proportion to the increase in carbon and strength. Manganese hardens steel and renders it brittle, and adds to its strength, much like carbon, but in less degree, while, at the same time, it does not seem as rapidly as carbon to diminish the ductility, or percentage of elongation, proportional to the increase of manganese and strength.

Now it will be noticed that it is said of each of these four substances, phosphorus, silicon, carbon, and manganese, that they harden steel and render it brittle. Phosphorus and silicon seem to harden steel without adding any other desirable qualities, except, perhaps, wear; while carbon and manganese seem likewise to have important influences upon the strength and ductility of the metal.

Leaving this point now for a moment, let us examine what qualities a steel rail needs to possess. A steel rail, as it seems to me, like every other piece of metal which is subject on the one hand to *strain*, and on the other, to *abrasion* or *wear*, has two things to avoid. On the one hand, it must not be so hard and brittle as to break under the strain or blows to which it is to be subjected; while on the other, it must not be so soft as to yield too rapidly to the abrasive action which it is to be called upon to withstand. If, now, this reasoning be correct, and if the influence which we have ascribed to the carbon, phosphorus, manganese, etc., be such as they actually possess, it would seem that we ought to find, by a study of the results of the chemical analyses—since the series analyzed embraces rails which have been broken or crushed in service, as well as those which have endured long and hard service—I say it would seem that we ought to find what amount of these hardeners or brittle-makers is so great that the rails have a tendency to break or crush in service; and this point being known, it is obvious that to get the most satisfactory wear, it is only necessary to have the rails as hard as they can be made with safety. In other words, if the limit of hardeners or brittle-makers is known, it is obviously good policy to make our rails approach this limit as closely as possible.[1]

A word now as to method of studying the hardeners. If we take any single hardener and follow it through the series, regarding it alone as to its influence on the steel, we will usually find that the principal thing that we will learn will be, that if any one of these hardeners is very high the rail broke in actual service. We will also learn that in the 12 rails which did not break or crush in service, the average of the carbon is 0·287 per cent., while in those which did break or crush in service it is 0·366 per cent.; while in the 11 rails which withstood the highest tonnage, the average carbon is 0·30 per cent. Also, that in the 12 rails which did not break or crush in service, the average of the phosphorus is 0·077 per cent.; while in those rails which did break or crush in service, the average of the phosphorus is 0·132 per cent. And just here I may be permitted to call attention to what seems to me a very significant fact, viz., that in every case in which the phosphorus is above 0·12 per cent. the rail either broke or crushed in service. We will also learn by inspecting the analyses as to single elements, that the average manganese in the rails which did not crush or break is 0·369 per cent.; while the average in those which did crush or break is 0·521 per cent., and that the average silicon in the unbroken rails is 0·044 per cent., while in the broken or crushed rails it is 0·047 per cent.

---

[1] In connection with this paragraph, upon the relation between the hardness and wearing quality of steel, I would like to call attention to a more full discussion of this question in a paper in these proceedings under the title, "Does the Wearing Power of Steel Rails increase with the Hardness of the Steel?" As will be seen there, the reasoning given above does not seem to be fully sustained by the facts in the case. (Oct. 12th, 1878.) [This paper will appear in our next number.—Ed.]

But it seems to me that the true way to study the influence of the carbon, phosphorus, etc., upon steel is not to regard each one separately, but since all are known to render steel hard and brittle, to consider them *all as hardeners or brittle makers*, and study them in connection with each other. There are two ways in which this may be done.

(1.) We may simply add together the percentages of carbon, phosphorus, silicon and manganese, as they are given in the analysis, the sum obtained being regarded, of course, as a comparative measure of the hardness of the steel. Doing this, and we find that the average sum of these constituents in those rails which did not break or crush in service, amounts to 0·778 per cent.; while in those rails which did crush or break it is 1·030 per cent. It would, therefore, almost seem fair to conclude that we cannot with safety have the total sum of the carbon, phosphorus, silicon and manganese in our rails as high as one per cent.

(2.) There is another way of looking at these results of analysis which seems to lead to even better results than are obtained by simply adding together the percentages of the hardeners. It is a question which has been somewhat discussed among metallurgists, how much carbon, for example, would have the same influence in rendering a steel hard and brittle as 0·01 per cent. of phosphorus. Or again, how much silicon or manganese would have the same influence in this respect as 0·01 per cent. of phosphorus. I am not aware that any definite relations have ever been discovered between these substances in this respect. But it is, of course, evident if we wish to express numerically the hardness of steel as derived from its chemical composition, we must estimate the influence of each of the hardeners in the same unit. Now I have assumed 0·01 per cent. of phosphorus as the unit of measurement, and have called this 0·01 per cent. a phosphorus unit. I have likewise assumed that 0·02 per cent. of silicon, 0·03 per cent of carbon, and 0.05 per cent. of manganese have each the same influence in rendering a steel hard and brittle as 0·01 per cent. of phosphorus. In any analysis of steel, therefore, the phosphorus units are found by adding together the phosphorus, $\frac{1}{2}$ the silicon, $\frac{1}{3}$ the carbon, and $\frac{1}{5}$ the manganese, expressed in hundredths per cent. Applying these data to the chemical analyses of the series and we find that the average sum of the hardeners—expressed in phosphorus units—in the rails which did not break or crush in service is 27, while the average sum of those which did break or crush is 38. Examining now Table III. a little in detail and we find that with one exception, No. 395, the total sum of the phosphorus units in the good rails in no case exceeds 31, while most of them are 29 or below; while, when we examine those rails which either crushed or broke in service, in no case is the total sum of the phosphorus units less than 33. It would almost seem fair to conclude, therefore, that, measured in phosphorus units, in the manner described, we cannot have rails whose total sum of hardeners in phosphorus units is over 31 or 32. Now, as has already been stated, I think no one will affirm that for successful wear the hardeners should be lower than is consistent with safety.[1] But in the rails which have not broken or crushed in service we find only one, No. 395, whose sum of hardeners is over 31. Therefore, measured in phosphorus units, it seems clear that the sum of the hardeners in rails for use on Pennsylvania Railroad should not vary far from 30. The "total hardeners" and "phosphorus units" given in the pages of this report, which contain the diagrams of the rails analyzed, are obtained in the manner described above.

And now, how shall the hardeners be distributed? It has already been mentioned that in every case where the phosphorus is above 0·12 per cent., the rail either crushed or broke in service. Examining the phosphorus in rails which did not crush or break in service, we find that in no case is it above 0·11$\frac{1}{2}$ per cent., while in almost every case it is below 0·09 per cent. Remembering now that phosphorus makes steel brittle and especially liable to fracture from blows, and it would, perhaps, seem fair to place the limit of phosphorus at 0·10 per cent. As to silicon, the less in the rail the better. Nevertheless, as by the Bessemer process it is impossible to make rails entirely free from silicon, a small limit must be allowed for silicon. As the process is ordinarily worked, perhaps 0·04 per cent. will not be too high a limit.

---

[1] See Note to page 383.

The ability of rail-manufacturers to control the amount of carbon and manganese in the steel, requires a little broader limits for these two elements. If, now, we place the carbon at from 0·25 per cent. to 0·35 per cent., and the manganese at from 0·30 per cent. to 0·40 per cent., and are able to obtain rails on this formula, which are not injured or spoiled during the manufacture, I think we will get rails which will be entirely safe, and, at the same time, give satisfactory wear. The sum of the hardeners, measured in phosphorus units, for the limits of the formula, amounts to 26 for the lower limits of carbon and manganese, and to 32 for the higher. In view of the tendency to higher carbon which has seemed to prevail for a few years past in rail manufacture, it may appear that the carbon limits given above are low. But that this is correct will, I think, be evident from the considerations which follow. Of course if we could make a formula just as we would like, it would, perhaps, be entirely scientific to take the average of the carbon, phosphorus, manganese, etc., in the best rails as the standard for this formula. Doing this for the rails which did not crush or break in service and we have, carbon, 0·287 per cent.; phosphorus, 0·077 per cent.; manganese, 0·369 per cent.; silicon, 0·044 per cent.; and the same for the 11 rails which withstood the highest tonnage, and we have, carbon, 0·30 per cent.; phosphorus, 0·091 per cent.; manganese, 0·38 per cent.; silicon, 0·045 per cent. But in view of the difficulty of obtaining low phosphorus in this country, we have put it as high perhaps as it should be, viz.: 0·10 per cent. If, now, we make high carbon, we must diminish the manganese, or our total hardeners will be too high. That carbon should not be increased at the expense of manganese will, I think, be evident from an examination of the formula given just above, derived from the average composition of the best rails, as well as the separate analyses in Table III.

Both the formulas given above show the carbon to be lower than the manganese, and both are within the limits which we have given for carbon and manganese, viz.: 0·25 per cent. to 0·35 per cent. for carbon and 0·30 per cent. to 0·40 per cent. for manganese. Again, in the separate analyses of the rails which did not crush or break in service, in only one case, No. 413, is the carbon higher than the manganese. Moreover, if the influence which we have ascribed to manganese, viz., that it increases strength and hardness of steel without diminishing elongation as much as carbon would do, be correct, the rails which we get on a formula in which manganese is higher than carbon, will be less liable to break or crush in service, and at the same time will, perhaps, give as satisfactory wear as if the carbon had been increased and the manganese diminished.

II.—Physical Tests and Inspection.

The question now arises what physical tests and inspection shall the Pennsylvania Railroad Company prescribe to the rail manufacturers to enable it to secure rails uniform in quality?

The inspection which is at present employed seems to be amply sufficient to enable us to discard rails whose defects are evident to the eye. The question as to physical tests is not so easily answered. Nevertheless, three methods of applying physical tests suggest themselves.

(1.) The bending test now it use. It seems to me fatal to this test as at present conducted that the test bar, ¾ inch square by 12 inches long, is hammered out from a piece of the rail. It is conceded, I think, that in proper hands a piece of steel is changed by hammering. We are, therefore, not testing the steel in the rails, but a different quality of steel. If the present bending test is to be continued, I would suggest that the test bar be cut from the rail head, instead of hammered from it.

(2.) The Drop Test. This test was in use for some time on the road to determine the quality and uniformity of the rails purchased. With regard to this test it may be said that unless the foundations are very solid, much of the force of the blow is lost; so that a rail tested under a rickety drop might stand the prescribed test, which, under a firm one would yield. It would seem, therefore, that the drop test, without extreme care and inspection on the part of the railroad company to hold the rail manufacturers up to specifications, would give erroneous results. It is due to this reason, as I understand, that the drop test was abandoned.

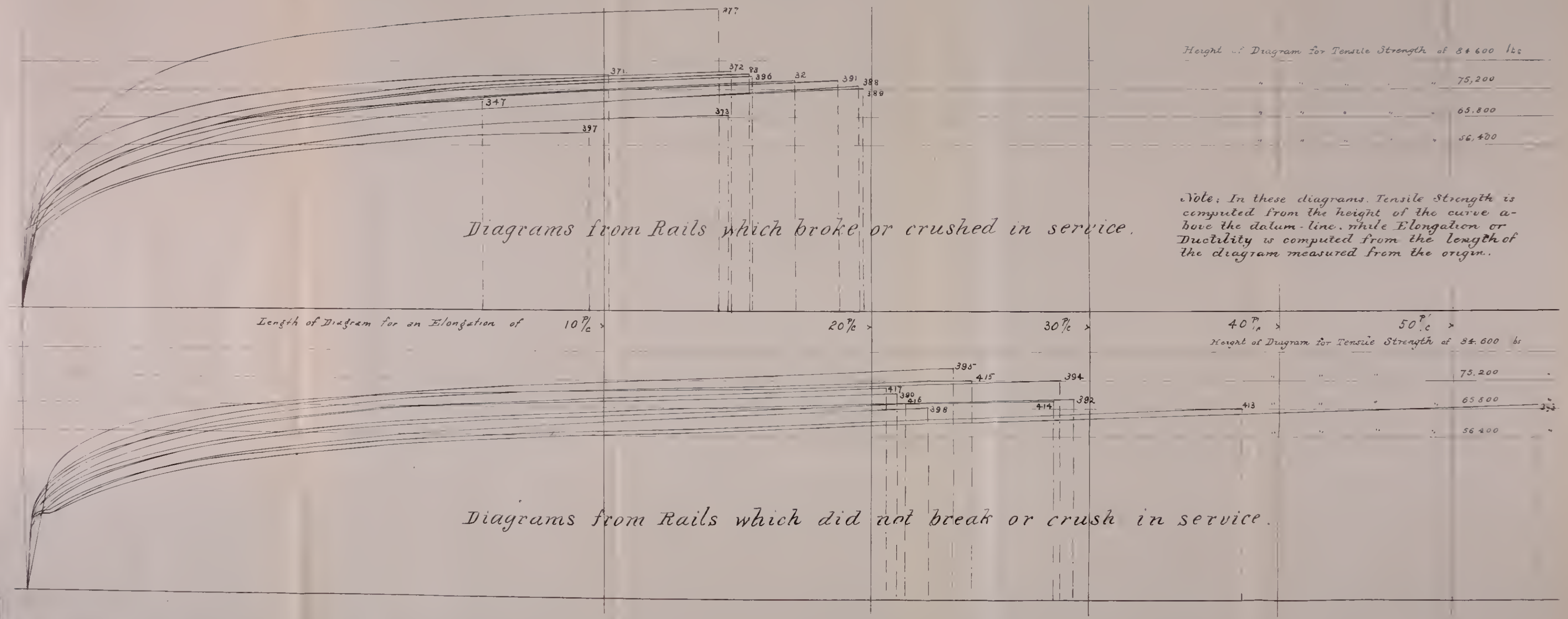
(3.) Still another method of testing our rails suggests itself, and that is to ask the rail manufactures to provide themselves with and use the same kind of machine upon which the physical tests of the series of rails analyzed have been made, viz.: Thurston's Torsional Testing Machine. That this would be the most valuable method of securing uniformity in the rails furnished us, will be evident, it seems to me, from a study of the physical tests in Table III. It should be stated here that of all the data in regard to the physical qualities of metal furnished by this machine, which data are given in full for record, in connection with the analyses, in the preceding pages, and are tabulated in Table II; we have selected out two, viz.: Tensile Strength and Percentage of Elongation, as best expressing the value of the steel with our present knowledge of the subject. It should also be stated that the tensile strength given in this report is $\frac{94}{100}$ of that obtained by the formula for determining the tensile strength which accompanies the machine, this being found by comparative tensile and torsion tests to most nearly express the tensile strength of this grade of steel.

Turning now our attention to Table III to the rails which crushed or broke in service, and noting that in the case of No. 397 the test is not very reliable on account of inability to secure a full size test piece from the rail sent for analysis, and we find that in every case except two, No. 373 and 347, the tensile strength of these rails is 75,000 pounds or above per square inch, while the percentage of elongation is 20 per cent. or below. Turning, now, to the rails which did not break or crush in service and we find, with the single exception of No. 395, the tensile strength is between 65,000 pounds and 75,000 pounds per square inch, while the percentage of elongation is 21 per cent., or above. If, therefore, we had had specifications that our rails should have a tensile strength above 65,000 pounds per square inch, and a percentage of elongation above 20 per cent., as determined by the machine referred to, a simple inspection of Table III. shows absolutely that we would have been able to reject every rail in this series which has crushed or broken in service. The same facts, and especially the defective elongation of the rails which broke or crushed in service is made evident to the eye by an inspection of the accompanying diagrams of tests of the rails analyzed and described in this report, and from which the physical tests given in this report were computed.

THE CHEMICAL COMPOSITION AND PHYSICAL PROPERTIES OF STEEL RAILS.

By C. B. DUDLEY, Ph. D., Chemist, Penn. R. R. Co.

Altoona, Pa., Nov., 1877.



Diagrams from Rails which broke or crushed in service.

Note: In these diagrams Tensile Strength is computed from the height of the curve above the datum-line, while Elongation or Ductility is computed from the length of the diagram measured from the origin.

Diagrams from Rails which did not break or crush in service.

In view of the discussion and considerations given above, it seems fair to conclude:—

(1.) That with our present metallurgical methods high phosphorus in rails is inconsistent with safety.

(2.) That silicon should be as low as is consistent with the successful working of the Bessemer process.

(3.) That the best range for carbon is from 0·25 per cent. to 0·35 per cent.

(4.) That the best range for manganese, all things considered, is from 0·30 per cent. to 0·40 per cent.

(5.) That the total sum of the hardeners, expressed in phosphorus units in the manner described, should not be above 31 or 32, nor below 25.

(6.) That the tensile strength of rails for use on the Pennsylvania Railroad, determined in the manner described in this report, should be above 65,000 pounds per square inch, and that the percentage of elongation determined in the same manner should be above 20 per cent.

I would, therefore, respectfully recommend that the following formula be prescribed for the chemical composition of rails for the use of the Pennsylvania Railroad, viz.:

Phosphorus, not above	0·10 per cent.
Silicon, " "	0.04 "
Carbon, between 0·25 and 0·35 per cent., with an aim at	0·30 "
Manganese, between 0·30 and 0.40 per cent. with an aim at	0·35 "
Sulphur and Copper,	No specifications.
All other impurities, not more than traces.	

Also, that the rail manufacturers be requested to procure one of Prof. R. H. Thurston's Torsional Testing Machines, and to furnish test pieces from each "blow," ready for testing, to our Rail Inspector, or other person authorized to attend to that work, who shall test the same on this machine, and that we shall be at liberty to reject all "blows" which do not conform to the physical tests, shown to be essential in the body of this report.

And I would also recommend that the rail manufacturers be informed that we feel ourselves at liberty, at any time, to make chemical analyses of the rails furnished us, and if at any time the rails are found to differ from the above specifications, it will be regarded as a breach of contract and a proper subject for adjudication.

Very truly yours,
CHAS. B. DUDLEY,
ALTOONA, *Nov. 13th*, 1877. *Chemist Penna. R. R. Co.*

EFFECT OF THE MOTION OF THE AIR WITHIN AN AUDITORIUM UPON ITS ACOUSTIC QUALITIES.

By W. W. JACQUES,
Fellow in Physics of the Johns Hopkins University.

It is the purpose of this paper to give an account of some experiments made for the purpose of determining the effects of the currents of air within an auditorium, upon its acoustic qualities. These experiments are in three series. The first being a laboratory investigation into the effects of currents of air upon a ray of sound. The second and third, studies, by different methods, of the effects of the currents of air in a lecture hall and a theatre, upon the waves of sound.

Since the air of a hall is the medium by which sound is conveyed from the speaker or singer to the hearer, it would certainly seem of fundamental importance that this air should be in the condition best suited to the propagation of sound. Experiments made by the author, in a considerable number of halls, show that the atmosphere is almost invariably disturbed by currents of air of varying density crossing the room in all directions. These currents have been traced out with thistle balls and their velocity measured with the anemometer. The estimates of density have been made from the velocity of motion. Now the experiments of Prof. Tyndall have shown that currents of air of varying density form one of the chief obstacles to the propagation of sound-waves. The author, in repeating these experiments in a somewhat modified form, found that such currents of air not only decrease the intensity of a sound-wave, as Prof. Tyndall has shown, but that they actually modify its form, and so give rise to great indistinctness. The experiments were made as follows: At *A* was placed a source of sound,

$$A + - + - + - + - + E,$$

being in some cases an organ-pipe, in others, a man who spoke in a clear and distinct voice, and in others, various musical instruments, on which simple combinations of notes were played. Just below the points, + +, etc., were placed substances heated to such temperatures as to give rise to currents of air corresponding in density to those found in an auditorium. At *E* was placed the ear, which, though it be not so reliable an instrument as the singing flame of Prof. Tyndall for estimating intensities of sound, is, of course, the best instrument imaginable for determining their qualities. The results of the experiments were as follows: The ear being placed at *E*, and a small lead organ-pipe, blown with a constant pressure of air, at *A*, the heated bodies were placed under + +, etc. A very decided decrease in the intensity of sound was noticed; but it was also noticed that the previously clear note lost its *distinctness.* The pipe was removed, and a man was placed at *A*, who spoke in clear and well-defined tones. The effect was not only to decrease the intensity of his voice, but to make it slightly confused and indistinct, as if each syllable were repeated several times in very close succession. When a flute was substituted for the voice, the effect was the same. The effect on a violin seemed to be considerably less. With a drum, no effect whatever was observed. The effect seemed to be most marked on the man's voice, or a musical instrument in which the overtones were comparatively small. The explanation of this is very simple. The original ray of sound, striking upon the first current of air, is partially reflected and partially transmitted. The loss of the reflected portion causes a decrease in the intensity of sound. The transmitted portion, striking upon a second current, is likewise divided, and its transmitted portion continues to be so divided as many times as there are variations in the density of the air. Its reflected portion, as well as that of all the succeeding reflections, instead of being wholly lost, is interrupted in its backward course by the first current of air, and reflected along the path of the primary wave, but following it at an interval of time, depending upon the thickness of the current of air. Each reflection being thus again and again reflected and divided, we have, following close upon the primary wave, a multitude of secondary waves, which, falling upon the ear, greatly mask the distinctness of the original sound. Currents of air of varying density then cause, first, a *decrease in intensity* of sound, and secondly, an *indistinctness*, or confusion of the sound.

That currents of air, which we have thus studied in the laboratory, act in the same way in an auditorium, may be shown by the following experiment, in which the sound-waves may be actually traced out in space, and their confusion, consequent upon the introduction of currents of air, likewise shown.

Near the middle of a lecture hall, 92 feet long and 65 feet wide (the hall of the Massachusetts Institute of Technology, in Boston), a heavy plank, six feet wide and twelve feet long, was set on one end and firmly fixed. Eight feet from its middle point, on one side, was placed a B 4 stopped lead organ-pipe, which was so connected with a gasometer as to be blown with a constant pressure of air.

On the other side of the plank, and within the sound shadow, a system of coördinates, in a plane parallel with the floor, was established, by means of light wooden rods, which ran parallel and perpendicular to the board, and their length divided into centimetres.

Now it has been shown by the author (*Prac. Am. Acad. Arts and Sciences*, May 10th, 1876), that rays of sound diverging from such a source, and being diffracted around the edges of the board, will, when they meet each other, after having passed over paths differing by a half wave-length, neutralize each other and produce comparative silence. By moving a B 4 resonator, connected by means of a rubber tube with the ear, along these coördinates, the points of interference are easily detected and are found to be situated as predicted by formulæ similar to those used in the diffraction of light. In fact, the cases are entirely analogous.

We have here, then, a means of mapping out the positions of the sound-waves in space, and can say that at one point there is silence, because two sound-waves have met crest upon the trough, and neutralized; at another the sound is loud because two waves have met, crest and crest, and trough and trough, and have doubled. All this is true so long as the air of the hall is at rest, and these experiments have been made with doors, windows and registers carefully closed.

Everything being in this condition and the sound-waves having been mapped out, the doors and windows were thrown open to the winter's air, and the registers were opened to admit as many streams of air heated to nearly 100° C. What is the effect? Currents are rushing about the hall in every direction (we have the conditions of the laboratory experiment), the waves of sound are superimposed by numberless reflections whose points of condensation do not coincide, and the phenomena of diffraction instantly disappears. This experiment was many times repeated, and always with the same results.

It is evident, then, that in order to procure the proper propagation of sound, we must do away with these air-currents. It must be remembered, however, that when large numbers of persons are crowded into halls, the air within is usually subjected to very considerable disturbances in order to obtain even indifferent ventilation. How, then, shall we obtain the desired ventilation and at the same time prevent the formation of currents of air?

The solution of this problem seems to me to be given in the third series of experiments, which were carried out in the "Baltimore Academy of Music," designed by Mr. J. Crawford Neilson, architect, of that city.

The ventilation of this house is so arranged as to prevent largely the formation of air-currents of unequal density. According to a survey, made with thistle balls and the anemometer, of the space contained within the walls of this theatre, the movement of the air is as follows:

The whole supply of fresh air is admitted at the back of the stage, is there warmed, then crosses the stage horizontally, passes through the proscenium and then, somewhat diagonally towards the roof, across the auditorium in one grand volume and with gentle motion so as to almost entirely prevent the formation of minor air-currents. It is exhausted partially by an outlet in the roof and partly by numerous registers in the ceilings of the galleries. From this central outlet and from the large flues of the registers the air passes into the ventilating-tower over the great chandelier, which supplies, in its heat, a part of the motive power of the circulation. It is further expelled from the tower by means of large valves so contrived that, while they offer no obstacle to the *egress of air*, they completely *deny it entrance.* The amount of air so passed through the house is, as determined by a series of experiments, about fifteen thousand feet per minute. This amount, sufficient to ventilate the house, is just what seems to be required to impress the proper movement on its atmosphere. That it is amply sufficient for ventilation is shown by the fact that the thermometers of the upper circle do not vary perceptibly from those of the orchestra circle.

The seating capacity of the house is about sixteen hundred persons. The acoustics are, if we may judge from the testimony of a large number of singers and speakers, as well as from our own observation, among the best.

The weakest voice is audible to every seat in the house, sounds such as a sigh, a kiss, or even the simulated breathing of the somnambulist may be heard in the most distant parts, and all effects in music are exactly rendered. All singers and speakers agree in describing the facility with which the voice is used on this stage.

It now remains to show that the universally acknowledged acoustics of this house are largely due to the *condition of the air*, and not to the arrangement and material of the walls, together with other well-known causes of success or defect. For this purpose, persons have been repeatedly stationed at different parts of the house during a performance, without being informed of the nature of the experiments to be carried out. They have simply been asked to note, at intervals during the evening, the comparative ease with which they could hear the performers. At various intervals during the evening, the valves which control the ventilation were reversed, so as to entirely interfere with the unbroken condition of the air, and give rise to currents of circulation. Almost invariably the testimony of the hearers would be, that at times corresponding to the interruption of the ventilation, the "sound was dead," was "confused and indistinct," and it would be observed that people all over the house would make an effort to listen. As an example of these experiments, the following is copied from the author's notes, for the evening of January 24th, 1878.

There was a concert, consisting of orchestral music and solos, held in the house. At eight o'clock, observers, A, B, C and D, were stationed respectively in the orchestra, right and left wings of the balcony, and on the bridge that spans the stage above the level of the highest proscenium boxes. They were entirely ignorant of the nature of the experiment, and were simply requested to note the times of good and bad hearing.

At half-past eight o'clock the valves were reversed, and remained so till nine, when they were again set aright; after the performance, the following testimony was given by the different observers:

A.—Orchestra—to 9.15, very indistinct; 9.15 to 10, much better.

B.—Right Balcony—8.45 to 9.15, sound was dead; 9.15 to 10, decidedly better.

C.—Left Balcony—8.00 to 8.40, good; 8.40 to 9.15 confused; 9.15 to 10, good.

D.—*Over* Stage—8.00 to 8.30, good; 8.30 to 9.00, strong draught, hearing better; 9.10, draught disappeared.

An examination of this table shows that the observers in the auditorium found a period of half an hour's duration when the sound was not so plain as it had been before, or was after. This time was of the same length, but from 10 to 15 minutes later than the period of interruption of the ventilation; but some time is, of course, necessary for the air-currents to form, or, being formed, for them to be destroyed.

The observer, D, over the stage, however, found the hearing *better* during the half hour of interruption, and this is exactly what would be expected; for the interruption of the current of air through the auditorium, causes it instead to rise directly over the stage into the large space in which hangs the scenery, and thence out of the building.

During Neilson's performance of "Rosalind," observers A and B were stationed in the first and C and D in the second balcony from 8.00 to 10.00 P. M. At 8.50 o'clock the ventilators were closed and the lobby doors, together with those leading from the lobby to the street, were thrown open.

Thistle balls let loose from the balconies showed currents of air coming in at the doors and crossing the auditorium towards the stage. At 9.20 the doors were closed and ventilating-valves set aright. The testimony of the observers was as follows:

A.—First Balcony—8.00 to nearly 9.00, good; for about half an hour, bad; afterwards, much better.

B.—First Balcony—8.00 to 9.00, good; 9.00 to 9.30, bad; 9.30 to 10.00, good; strong current of air felt from the door a little before 9.00.

C.—Second Balcony—8.00 to 8.50, good; 8.50 to 9.20, bad; 9.20 to 10.00, good.

D.—Second Balcony—8.00 to about 9.00, good; 9.00 to 9.20, bad; 9.20 to 10.00, good.

In the foregoing paper we have studied the effects of air-currents upon the acoustic qualities of an auditorium. That this is only one of the factors on which success depends the author knows full well, and experiments are now in progress upon some of the other causes which modify the acoustic properties of churches, theatres and halls.

These, however, have been in part studied before, while the above researches are believed to be entirely new.

ON FURTHER APPLICATIONS OF THE FLOW OF SOLIDS.

By M. Henri Tresca, President of the Societé des Ingénieurs Civiles, Paris.

(Concluded from Vol. lxxvi, page 334.)

An entirely different effect is produced when a medal is struck. The blank piece having been placed in the matrix, the portions which are not to be raised in relief by the action of the press are reduced in thickness, for the benefit of the neighboring portions which are raised; the metal literally flowing, in radial directions, from the hollows to the reliefs by which they are surrounded.

If the medal has only an engraved face, it may be made up of several blanks of equal thickness superposed. The same mode of distribution of the molecules takes place, and is manifested by successive imprinting at each face, in which the final relief is more or less obliterated.

It is so clearly a manifestation of flow that takes place under these conditions, that if the bottom of the matrix be hollowed out at the centre, then, the material which converges from the circumference exciting a pressure towards the centre, the central portion of the blank is driven towards the orifice, where it forms a very regularly shaped boss; admitting of the transformation of a relief executed on a plane, into a similar relief on a surface which has become very convex or very concave, according as the design pertains to the upper or the lower face of the blank.

To an analagous cause, the presence of scars sometimes observed on medals highly relieved, is to be attributed; these scars being produced simply by the junction, during the latter strokes, of the edges of the bosses which are formed by the earlier strokes.

When the medal is relieved on both faces, if it be made up of several plates superposed, it is interesting to remark the successive developments and effacements of the images on both sides of the plates; mingling and merging in each other in a singular manner.

Rules cannot yet be formulated for the best forms of the grooves of rolls; but it may be accepted that they should be shaped in such a manner as to utilize as far as possible the natural flow of the metal in the direction of the pressures applied to it.

It has been shown that when a bar is to be drawn out, it is best to prevent any enlargement of it laterally, and to facilitate the longitudinal flow: the die should, therefore, be carefully gauged, short, and opened out in the direction of the length.

It has been seen, also, that in stamping a disk, it may be useful to make use of centripetal compression. Each mode of action has thus its own mode of deformation of which it is necessary to know how to take advantage. The following is a very remarkable instance: Given a disk of lead 4 inches in diameter and $\frac{1}{8}$ inch thick: if it be pressed, in the stamping machine, for a diameter of $2\frac{1}{2}$ inches at the centre, the thinning of this central portion is only effected by the flow of the material outwards: and this flow is exactly symmetrical, when the centering is perfect. The exterior border is developed in the form of a tulip. By such means, without the employment of a matrix, geometrical forms of a perfectly definite character may be produced, which may be useful in some cases.

This general disposition of material had been long since observed by MM. Piabert and Morin, in the course of their experiments in drawing out blocks of clay. Around the orifice of entry the clay was thrown out in the form of acanthus leaves, and the same development is to be observed in the displacements which take place when projectiles are discharged against armor plates. The metal displaced by the projectile is driven forward in flakes or strata more or less involved and dislocated, which have, nevertheless, a striking family likeness to the dispositions previously noticed.

The geometrical condition of the development in tulip-form of the plate of lead, may be very simply explained. The border of the plate, which makes an effort to retain unaltered its diameter and its thickness, continues to be attached to the central portion, the gradual crushing of which throws out rings which are successively thinner and thinner. These rings have, therefore, at each instant, a given thickness, and by their succession they necessarily form a surface of revolution, which is accurately calculable, on the hypothesis, which is perfectly justifiable, that the volume is constant.

The conditions of such development may be modified by the employment of casings of various forms, but attention will be confined to the case of a concentric casing so disposed as to prevent any increase of diameter.

Eight disks of lead $1\frac{1}{2}$ inches in diameter have been placed in a cylinder, a piston of 1·20 inches in diameter is placed upon the pile formed by these plates. Since the material can only escape from the compressive action by the annular space comprised between the piston and the cylinder, it ultimately assumes the form of a sort of tumbler, of which the height is extended to the length of the piston, even beyond the length of the cylinder. The thickness of the tumbler, 0·15 inch, would have been more regular if but one disk of lead, or of tin, had been employed. But the mode of distribution of the layers in the thickness of the tumbler is in itself a useful subject for consideration. The uppermost plate has been developed, almost in one piece, to the upper edge of the tumbler, being connected by a continuous supplementary part, which becomes gradually thinner until it reaches the foot of the tumbler. The other plates are also developed, in a parallel direction, supported by the sides of the cylinder, for a length which may be submitted to the same kind of calculation as that of the plates of the concentric jets. It is the same mode of deformation applied, in the present case, to an annular jet; and the complete analogy between the formulæ which give expression to their relations is not one of the least remarkable facts in these transformations.

This method has for several years been adopted in industrial operations, under conditions of precision which are truly astonishing, in which a vertical and cylindrical jet, 12 inches high, is manufactured from a sheet of tin perfectly smooth and of uniform thickness. In the finest specimens of that size, the ends of the tube, which are pared after having been struck, do not show any irregularity exceeding $\frac{1}{12}$ inch in height, even though the cylindrical envelope has been suppressed for the whole height. The substance driven out in the form of a ring, the thickness of which is measured by the difference between the radius of the punch and that of the matrix, is naturally disposed to form a thin cylinder, the several elements of which slide with equal facility upon the perfectly polished surface of the punch.

A thousand examples of similar surprises may be found in industrial processes; but this instance, amongst them all, definitively sanctions the expression by which the author believes he is authorized to designate the results of his researches. The flow of solids is now recognized in science; much more will it be accepted by the members, who are witnesses every day of the processes which are based upon it, as the true expression of the best ascertained facts.

Planing.—Of the various operations which have been described above, that of punching is the only one which has had for its object the dividing of a solid body, and forming two entirely separate parts —the burr and the punched block. The block is augmented by compression of a portion of the matter which constituted the cylinder which would have been simply pushed out by the punch, supposing that the cylinder could have slipped out without giving rise to other phenomena. The burr is reduced by the same amount.

Cutting or shearing does not really take place until the moment when the burr, in consequence of lateral flow, has been reduced to its final height. It has been proved that from this moment the resistance opposed to shearing is actually proportional to the area of the zone of shearing. The coefficient of resistance applicable to this separation is no other than the coefficient of resistance of fluidity; or what amounts to the same thing, the coefficient of resistance to rupture; so that we are now put in possession of a certain formula, applicable equally to circular shearing by the action of the punch, and to rectilinear shearing by the shear blade or by the turning tool.

In each case one of the parts of the piece slides upon the other part, producing at the two sides in contact a drawing out of the successive layers, which are bent over in the direction of the length of the shorn surface, in thin shreds, like those produced by the punch. The separation only really takes place at the moment when these shreds are drawn to their extreme limit of tenuity.

This characteristic of the separated surfaces is met with in planing, although the principal circumstances may here be entirely different; not less remarkable, however.

The principal difference consists in this, that the chief compression takes place not in the solid mass as before, but in the cutting which is detached by the tool, which, as it forms the exterior portion, opposes to the flow the least resistance. If the cutting be compared with the space which it occupied in the block before separation, it is easily observed that it is at the same time considerably shortened, and that, consequently, its thickness has been augmented in the inverse ratio of the shortening.

This leading fact in planing is very well exemplified in the turning from the wheel-tyre of a locomotive, comprising a cutting from the rivets. These are represented as of an elliptical section, $1\frac{1}{8}$ inches by $\frac{4}{10}$ inches, showing that the reduction in length affected by the action of planing was in the ratio of 10 to 28, or 0·36. This coefficient of reduction is still much greater than it is in many other circumstances; for the thinnest cuttings, the coefficient is occasionally as low as 0·10.

In another instance, a cutting planed off transversely from a double-headed rail, the height has not been altered, but the width has been reduced nearly in the same proportion as in the first example.

Another characteristic of cuttings produced by planing is that the surface of the cutting which rises from contact with the cutting-tool is always smooth, and is developed geometrically. That surface, in fact, is moulded on the tool during the process of deformation, and slides upon it in such a manner as to roll itself up in the form of a cone or of a cylinder. At this moment, above all others, the plasticity of the metal is brought into play; and if the original form of the cutting should interpose too serious obstacles to this development, it tears or splits according to the direction of the generating surfaces of contact, still responding to the geometrical condition first referred to. It is well to avoid such rents as much as possible, for evidently they cannot be produced without the expenditure of additional power. Such loss of power must take place, especially where it is required to reduce a curved surface at one cut, of great breadth. An example of such fissures is shown on about the third of the width of another cutting from a tyre; but those of the opposite edge are attributable really to a greater reduction of the length of the thinner edge in the process of planing.

The other face of the cuttings is always rugged and wrinkled with fissures or with transverse ridges, of every variable aspect, according as the metal is more ductile and the cutting is thicker. For the greater thicknesses both iron and steel present on that surface a multitude of inclined ridges partly covering one another: and of which the incline is still better defined where complete separation has been produced.

These scales have been drawn just as they appear under the microscope, on a cutting of Bessemer steel. Nothing can show better than their general inclination the sliding that may be produced in planing, in consequence of the compression which is produced in front of the tool before the cutting is completely detached from the block.

In the greater number of cases the turning when long enough winds up into a helicoidal form, as may be seen on the cutting, of which the rugged face has just been shown.

The inclination of the spirals depends upon that of the cutting edge of the tool, and their diameter upon the thickness of the cutting; the diameter diminishing with the percentage of reduction. It is thus that, in turning in the lathe a piece which is very slightly eccentric, the result is a number of parts of which the diameters are alternately greater and less. The demonstration afforded by this single specimen is quite complete.

Without seeking to draw any conclusions from the study of these deformations with respect to the best form of tools for each of them, it follows clearly from the foregoing discussion that the work required for any cutting action whatever is expended in friction and in deformation by compression. The work of friction should augment with the number of cuts, and as the shortening is greater for the finer cuts, the molecular work expended should be greater. It follows, therefore, that it is most advantageous to make deep cuts, but of course this mode of action demands more powerful tools and better foundations. It is in this direction, it appears, that the most recent progress in the manufacture of tools has been effected.

The different modes of cutting, rectilinear or circular, are applicable chiefly to flat surfaces and to cylindrical surfaces.

Flat surfaces are cut in the planing machine or in the lathe, and under most circumstances the two kinds of cuttings are almost identical in appearance—that of a cylinder formed of spirals more or less close, sometimes even in juxtaposition; but for this combination, it is necessary that the two edges of the cutting should have been equally reduced, that is, that they should be of the same thickness. If it were otherwise, the spirals would become conical; and such of these as appear to be most characteristic will now be described.

The cutting obtained in mortising, by means of a straight tool, is absolutely cylindrical.

When the tool cuts out, in this manner, a rectangular groove, the material is compressed without any lateral deviation. If the cutting is of great thickness, it is triangular, and the smooth surface is formed by the combination of the three faces at which the separation takes place, the direction in which crumpling takes place being the same as in all ordinary cuttings. The triangular form is the result of the compression being greater towards the middle line.

To aid in forming an opinion on this point, two blocks were placed side by side, which were planed at the same time, in the line of junction of the pieces. Two distinct horns were formed, which parted symmetrically from one another; each half-cutting following the law of shortening by which it was bound to assume a form concave towards the side which was held by its attachment to the block.

Having made a similar experiment in lead, the parallel and equidistant lines that were drawn upon the block before it was cut could be traced on the cutting, and they afforded the means of measuring exactly the average percentage of reduction, and the mode of contortion of these transverse lines, which assumed successively the same inclinations as they lay one upon another at intervals, of which the percentage of reduction varied from 0·10 to 1·30.

The cuttings from a lathe when they were produced from an annular groove, by means of a straight tool, assumed exactly the same forms. For example, a cutting from a groove in what is called the Swedish piston is a continuous ribbon rolled up as on a bobbin, with the greatest regularity, and of great length, without a rent.

When turnings take the form of a helix, the small lateral displacement of the piece is not large enough to give to the ribbon a different character to that of a planing machine, when, for instance, it is required to turn a shaft to a uniform diameter, and it is then easy, with good metal, to produce cuttings of great length. But, when it is required to turn the end of the shaft or of any cylinder whatever, the cutting follows a special course. If the tool be large in proportion to the diameter of the rings or circles on which it is acting, the difference of diameter between the two edges of the cutting makes itself felt in the cutting, which assumed the form of a helicoidal surface, with inclined generating lines, of which the directrices are two helices of the same pitch but of different diameters. This universal geometrical character, moreover, is manifested in special ways according to the width of the ribbon and the interior diameter of the ring. In this way three horns may be obtained, encased one in the other, if the cutting edge of the tool be radial. Successive spirals foul each other when the direction of the cutting edge is a little inclined. The inner helix is replaced by a straight edge when the tool cuts right to the centre of the face.

Notwithstanding these differences of detail, the same rules prevail: a greater or less reduction or shortening, according to the thickness of the cutting; a less reduction of length at the thicker edge of the cutting; a smooth surface of separation, which always forms a developable surface; a rugged reverse face ridged as if waves of metal had been successively projected there; in fact, all the circumstances of a transverse flow of material—setting apart the secondary circumstances, of transformation of the prism of metal from which the cutting is produced by augmentation of thickness and corresponding reduction of length.

The author endeavored to represent, by a diagram, the triangular cutting which would be formed by planing from the edge of a block of metal a square prism, by means of a tool having two cutting edges, and of which the flat front is itself placed symmetrically. The effect of the diagram, constructed on the assumption of a percentage of 0·30, is exactly reproduced by the model in relief. In agreement with the foregoing discussion and with the facts, it may be observed how the prism which is on the point of being separated from the block swells up by compression, commencing at a certain zone of fluidity, of limited length, in advance of the tool; and how, when this compression has arrived geometrically at the maximum which could be sustained by the material, the cutting is detached from the mass to be subjected to the action of the face of the tool, upon which it slides, and which forces it to assume its ultimate form.

Considerable as these modifications may appear, they are absolutely in accordance with the facts. They have been produced by the author, on lead as well as on the hard metals, under conditions which were exactly proportional to those which are represented by the model.

The finest specimens of this triangular transformation of cuttings that have come under the author's observation, are produced by a mortising tool. They are not less than $\frac{6}{10}$ inch thick, and the rolling up of the metal could only be effected with the accompaniment of deep fissures in the lateral edges. The upper edge, on the contrary, is much more minutely serrated, one of the lateral faces is plaited for its whole length, evidence of the compression of the material; whilst the other face, with its oblique fissures, shows still better the sliding by means of which the compression takes effect.

There is a still smaller cutting which presents exactly the same characteristics.

It is the author's opinion, that for the construction of the best machine tools, with the most suitable thickness of cuts, the minute examination of the cuttings is of the greatest importance; and that by the same means, the surest evidence may be derived with respect to the qualities and homogeneity of the metal.

Time does not permit of more than a passing reference to certain deformations which recall to mind, with a surprising degree of exactness, the constitution of certain rocks with their dislocations. A few experiments of this kind were made by the author in conjunction with M. Daubrée, from which the latter gentleman quite recently derived an explanation of a number of geological phenomena. The results of these inquiries would no doubt possess some interest for the members, but the author was desirous chiefly to lay before them such results of his investigations as followed in natural sequence upon the substance of the communication already made in 1867.

The idea of the flow of solids is, of all the modes of regarding their deformation, perhaps the one which most truly interprets all the phenomena of molecular mechanics, and of the internal constitution of bodies, which underlie the various industrial operations.

ON THE DIRECT PROCESS OF MAKING WROUGHT-IRON AND STEEL.[1]

By Charles M. DuPuy, C. E.

[Second Paper.]

About one year ago I had the honor of addressing this Institute on the direct manufacture of iron from the ore. I then briefly referred to the various efforts that had been made in that direction, reaching over the best part of the past century, and closed the paper by describing a method, which, from various experimental and practical tests, seemed likely to promise usefulness in the arts.

It may be remembered, by this process the ore, carbonaceous matter and fluxes, in the proper proportions, are ground together and mixed at the same time, and then filled into annular sheet-iron cases, holding from 100 to 200 pounds. Ten to twenty of these cases, with spaces between them, are subjected to the gradually increasing heat of a reverberatory furnace, and in about five hours, on the average, the ore and cases settle down, without work upon them, to about one-third their original height, becoming welded into quite compact lumps of iron, interspersed with liquid slag. These metal lumps are either then removed separately from the furnace, or several of them being welded together at the same heat, are forged or squeezed and rolled to "muck-bar."

---

[1] A paper read before the meeting of the Franklin Institute, Nov. 20th, 1878.

This process differs from all others, and it is exactly the reverse of the forge-fire and the blast-furnace methods. In *those*, a tuyere conducts a stream of oxygen into close contact with the particles of ore, while in *this* process the moderate heat prevents the combination of phosphorus with the iron, while atmospheric contact is excluded during reduction, and a reflected heat from the roof is furnished, for absorption during the transition to metal. It is to this peculiar treatment that is ascribed the high quality of the iron for steel purposes. It is what may be termed a *baking* process, which is conducted at a comparatively moderate heat to *eliminate phosphorus*, and in which the ore is kept out of the reach of oxidizing influences, and to this the high value for steel is attributable.

At the time I addressed you I had licensed Messrs. Miller, Metcalf & Parkin, of Pittsburg, Pa., to work the process at their Crescent Steel Works. Their forge and furnace was not completed until some time in last January, when for several months thereafter they carefully tested the iron which was deoxidized with charcoal by this method, in the various ways customary to determine the value of iron for high grades of steel. The result of these investigations brought forth the unqualified endorsement of this firm that the iron so produced from our native ores, for steel purposes, is equal in every respect to the most costly grades of Swedish iron.

Although the production of fine steel iron, reduced with charcoal by this process, was a step forward, yet the consumption of high grades of steel is comparatively limited, being mostly used only for tools of various kinds requiring great endurance. In order to enlarge the uses of this superior make of iron, it became apparent that its cost must be cheapened by deoxidizing the ore with waste anthracite dust or refuse coke-dust, instead of charcoal.

To determine the practical value of anthracite dust, a series of more than fifty experiments were conducted, during the month of August last, at the forge at Reading, Pa. In these experiments, with anthracite dust, were used magnetic ore from near West Point, N. Y., Dickinson ore from northern New Jersey, Cornwall ore from Lebanon Co., Pa., Cumberland Valley ore, from Maryland, Hematite ore from near Newark, Del., beside several other ores found near the line of the Phila. and Reading R. R.

These ores were worked both separately and variously combined. and with one exception, in every case, were reduced and forged to blooms. The blooms, which were reheated, were drawn out smoothly under the hammer. The tensile strength of one of these bars was tried, and found to not exceed 45,000 pounds to the square inch.

A couple of crucibles of steel were made from a part of the iron which had been reheated and drawn out, and the ingots were forged and used for planing tools. They stood forging and tempering well, comparing favorably, in endurance, with steel usually used in planing iron.

The object of testing iron reduced from the ore with *anthracite* coal-dust, for tool steel, was not so much with the expectation that at the first trial it would work well in planing iron in competition with steel carefully prepared from *charcoal* iron, but to determine, in a general way, the quality of the metal for steel purposes, of superior quality and in large quantities, by the open hearth. The result of this crucible test surpassed expectations and was very gratifying, from the fact that it is believed to have been the first instance where good tool steel was ever made by a direct process, on a practical scale, from iron deoxidized with *anthracite coal-dust*, and confirms the belief that anthracite dust will eventually be largely used to produce steel of high quality, cheaply, and in large quantities.

Besides testing the ores before named, at the Reading forge, iron scale from the rolls (which is almost pure oxide of iron) was reduced alone with anthracite dust, and was also mingled with ore and anthracite, and in both cases was found to forge well into good blooms.

At the same time with the foregoing experiments, the sulpho-oxides or refuse ore, remaining after extracting sulphur for sulphuric acid from the iron pyrites, at the New Jersey Chemical Works (commonly known to the trade as "Blue Billy"), was also reduced by this process with anthracite coal-dust, and forged well into a bloom. This specimen was sometime afterwards reheated, rolled, cut up and piled with about one-third of its weight of muck-bar from common puddled iron, and plated out well into smooth sheets of No. 26 iron. This last experiment is not of much value for this country, because very little sulphuric acid is made from pyrites, but in Europe probably not less than a million tons of this refuse ore is now annually almost wasted, because of the difficulty of economically utilizing it.

These Reading experiments were the more gratifying from the fact that the process was quite successfully conducted in a reverberatory furnace, not well adapted to the purpose. This furnace had some time before been specially arranged to test the use of anthracite coal-slack, by burning it in fires of four or five inches thickness, on what is commonly termed "the Wooten grate-bars." As these thin fires required renewal every fifteen or twenty minutes, the frequent opening of the door for replenishment exposed the ore so often to atmospheric reoxidation, as to make the furnace unsuited to the process. Besides this, the fire and flue bridge-walls, which had been constructed very low, and could not be very well raised owing to the lowness of the roof, caused the cases of ore to be exposed to the direct action of the blast and draft as it passed through the furnace into the stack.

Following up these interesting experiments, during the month of September last, a sand-bottom scrap-heating furnace was altered at the Sligo Iron Works at Pittsburg, for the purpose of testing this process further, by throwing the lumps of metal into a Burden Squeezer, and then rolling them to "muck-bar" at the same heat. Hitherto they had usually been forged to blooms under a hammer and afterwards reheated, to be drawn to bars.

This furnace was operated experimentally with 32 heats. There was found no difficulty in making balls to pass through the squeezer and muck rolls at the same heat, just as ordinary puddle balls from pig-iron is squeezed and rolled at the same heat to muck-bar, but in order to fill the squeezer, which required balls of 150 to 200 pounds to secure a good compression, it became necessary to weld and press several of the lumps of metal together, in the furnace, at a heat so high, as to cause the alkali to drip more or less from the mass, and soften the sand-bottom. As the balls were thus compressed and rolled in the fused sand, an unnecessarily large portion of the iron was thereby cut by the sand, and wasted to a silicate of iron, so that the yield from Republic ore which, before the bottom became softened produced

53 pounds of iron in muck-bar from 100 pounds of ore charged, and which it was expected would have been brought up to 60 pounds of iron from 100 pounds of ore, gradually became very much lessened, showing conclusively that reduced yield followed the softening of the bottom, and determined the necessity of a "*cinder-bottom*" in order to save the iron.

To compress and weld several of these masses of metal together in the furnace, in order to have them enter and fill the squeezer, *really comprised all the labor required during the heat.* The cases were 15 inches diameter and 14 inches high, holding about 135 pounds of ore besides the coke and fluxes. By making the cases very little larger, say 16 inches diameter and 16 inches high they would each produce about 100 pounds of iron, and by withdrawing each separately to the squeezer, all furnace manipulation of the metal would be avoided. Then, aside from maintaining the fire and charging and discharging the metal, all the labor really needed during the heat would be to change the damper once or twice, enabling an ordinary heater, to regulate all the furnaces in the largest mill.

The fire- or grate-surface of this Pittsburg furnace was 4 feet square, and the space between the bridge-walls was 9 feet by 5 feet in width. The bottom was of sand, set hard by heat. The flue-bridge was built up within 3 inches of the roof. The stack was 18 inches square inside. A fan-blast was used, part of the air passing under the grate-bars, and part, being heated, was passed through and over the fire-bridge.

In these several experiments it was found that although the opening between the flue-bridge and roof for the escape of the spent products of combustion, into the stack, was lessened more than one-half the size from what it was,-when, with less capacity, the furnace had been used for heating scrap-iron, still the heat was so intense as to soften and render useless the damper rod at the top of the stack, which had previously stood 12 years, requiring renewal three times during these experiments. The conclusion drawn from these accidents, was that the grate-surface of this furnace was amply sufficient to supply the accumulating heat for a length of 14 or 15 feet between the bridge-walls instead of 9 feet, thereby nearly doubling the capacity of the furnace with the same consumption of fuel.

Expensive fluxes, such as soda, manganese, etc., have been abandoned, as it has been now conclusively proved that a proper mixture of aluminous and silicious ores with lime, to produce a non-flowing glassy slag, is all that is required. This glassy slag being mingled among the particles of ore, covers and seals them from reoxidation from furnace heat during the process of reduction. When either of these glass-making constituents are not available, in the proper proportion, in the ore, ordinary sand or clay, in the proper proportions, may be added to the lime and mixed together, without injury to the metal, as the glass is readily compressed out of the iron by the hammer or squeezer.

During these experiments, No. 26 sheet-iron was rolled out at the mill from common puddle bar, being found to answer *equally as well for cases* as well finished sheets from the best iron.

It has now been demonstrated that good steel can be made by this process from iron deoxidized either with *charcoal*, *anthracite dust* or *coke-dust*. The carbon in all these fuels being alike, and as the ash of either, along with the earthy impurities of the ore, be they more or less, may be readily reduced to a glass, by a proper mixture of lime and ores, through chemical analysis, and so utilized as a covering of the metal during deoxidation, and compressed from it afterwards—it follows the truest commercial economy is found in using that form of carbon which is of least value.

In the coke-making bituminous regions, the refuse coke-dust is disposed of in waste heaps and often burnt; while from the beginning of anthracite mining, mountains of anthracite slack remain standing monuments of our wastefulness. These wasted fuels, by this process, offer a premium for the production of cheap steel.

Any process that will not withstand the closest economic scrutiny, is justly recognized as valueless in the arts; it is therefore proper to remark, that the investigations at Reading and Pittsburg during the past year, although conducted in furnaces not specially adapted to the process, and often amid inconveniences inseparable from experiments surrounded by the activity of regular mill-work, still nevertheless substantially confirm the view heretofore asserted, that a true commercial economy cannot fail to result from a systematic working of the process.

When it is considered that this mode of making iron *frees it almost entirely from phosphorus*, which goes almost altogether into the slag as explained in my former paper.

That a furnace at present prices for material and labor, in which from one ton to one and a half tons of blooms may be produced every 24 hours, will not cost over $800 to $1000.

That a little lime in combination with ore and waste coal-slack has been substituted for more expensive fluxes and is found sufficient to supply the glassy covering for the metal.

That No. 26 sheet-iron for cases is now found to be good enough *when plated out from common puddle bar*, and that the cases are very simply and cheaply made, needing neither tops nor bottoms.

That two men, in 10 hours, with a 15 horse-power engine, will grind, mix and fill the cases with the ore mixture for 7 tons of blooms.

That the furnace work is confined to charging, discharging and firing the furnace, *there being no necessity whatever for manipulating the metal from the time it is charged in the furnace until brought to the hammer or squeezer*, thus greatly simplifying and cheapening what by the puddling process is excessively laborious and expensive work.

That the masses of metal, as one by one they are squeezed to blooms, may then be transferred in the heated state, to the open-hearth bath, and there quickly melted along with the other steel-making material for the highest quality of steel.

When all these points are well considered it may be clearly understood that in localities as favorably situated for instance as the line of the Philadelphia and Reading Railroad, where Cornwall and other ores can be laid down at an average of $3 per ton, and where anthracite fuel and coal-dust may be obtained proportionally low—that blooms on a large practical working scale, nearly freed from phosphorus may be manufactured equally as good for $18 or $20 per ton, as now cost from $38 to $50 per ton. Similarly great inducements are likewise offered in Northern New Jersey, where fuel and ore can be brought together at about the same cost. In the bituminous coal region fuel is correspondingly low and coke-dust can be had for the freight, offering favorable manufacturing advantages.

In a few words, this process offers a cheap mode of making a high quality of metal for steel, by an inexpensive plant, enabling manufacturers to utilize idle rolling mills at trifling cost.

TESTS OF BOILER IRON IN THEIR RELATIONS TO THE PROVISIONS OF THE STEAMBOAT LAW.

By JAMES A. DUMONT,[1] Supervising Inspector-General of Steamboats.

One of the most important subjects connected with the steamboat inspection service is contained in the statutes referring to the quality of the iron plates to be used in the construction of boilers,—requiring the manufacturers of boiler-iron to guarantee its tensile strength, homogeneousness and toughness, as well as ability to withstand the effect of repeated heating and cooling,—for the use intended, and imposing pecuniary penalties, as well as imprisonment, for placing false stamps upon the same. Section 4430 R. S., also making it the duty of the Board of Supervising Inspectors to provide means for ascertaining that the law has been complied with, before such iron can be used in the construction of marine boilers; in pursuance thereof, that body has established rules for ascertaining the tensile strain only, leaving the other qualities to be decided by the individual judgment of the inspectors making the tests. The result of this, as asserted by manufacturers, has been to develope a disposition to secure the greatest amount of tensile strain possible, to accomplish which homogeneousness and toughness—elements fully as necessary to safety as tensile strength—have been sacrificed, experience failing to show a single instance of the rejection of boiler-plates, by the inspectors, except for deficiency in tensile strength.

The evils likely to follow such a course can be better understood when it is known that all manufacturers unite in admitting that tensile strength can be *increased* by combinations in the material, which *decrease* the other qualities. In other words, the harder and more brittle the iron, the greater the tensile strength. Many manufacturers assert that iron which shall contain all the requisites specified in the law, cannot be made to exceed 55,000 pounds tensile strain to the sectional square inch, yet by the table of pressures allowed by the Board of Supervising Inspectors, more steam is allowed a *hard, brittle* $\frac{1}{4}$ inch iron than is allowed to iron $\frac{5}{16}$ of an inch in thickness, containing all the lawful qualities, which is certainly wrong and decidedly unsafe if the theory of the manufacturers is correct. Therefore, the necessity is apparent that some definite, and generally acceptable rule should be arrived at for deciding this important matter.

---

[1] To be embodied in the Report of the Supervising Inspector-General of Steamboats.

Dr. Charles Huston, of Messrs. Huston, Penrose & Co., Coatesville, Pennsylvania, who has made many experiments with a view to a solution of this problem, and to whom I am indebted for many valuable suggestions, is inclined to think that the reduction of area, produced by tension in ascertaining tensile strength, indicates the possession or lack of the other necessary qualifications, according to the greater or lesser percentage of reduction shown, and that upon a minimum and maximum percentage of such reduction might be based a rule for the rejection of such plates as were below the former, as being too *hard* for boiler purposes.

The Society of Railroad Administration of Germany, has recommended its government to adopt 25 per cent. reduction of area as the standard of boiler iron in that country, on first quality of iron of a minimum breaking strain of 51,213 lbs., from which article, together with the experience acquired in testing the iron of the various manufacturers of this country, I deem it safe to assume that the object sought would be accomplished by adopting a minimum and maximum scale of reduced area at breaking point, demanding increased reduction, with increase of tensile strain with the minimum, for the lowest tensile strain to be not less than 15 per cent. reduction.

Below, I give the results of a series of tests, made in conjunction with Dr. Huston, of Coatesville, each experimenting on alternate samples from the same sheets, the main object of the experiments being for the purpose of ascertaining the relative strength of boiler-plate *with* and *across* the grain, while they show interesting results in many other respects than that for which they were made. In order to illustrate the experiments to the best advantage, they are here presented in the three following tables.

Nos. 124, 125, 148 and 149 were samples of $\frac{3}{8}$ iron, cut exactly the square of the thickness, and Nos. 131 and 132 were of the same iron, whose area approximated one-quarter of one square inch. Nos. 128 and 129 were of $\frac{1}{4}$ inch iron, reduced to the square of its thickness, while Nos. 135 and 136 of the same thickness, were

TABLE 1.—*Tests made at the Treasury Department—American Iron.*

Lengthwise of the Grain.			Crosswise of the Grain.		
Sample No.	Tensile strain per square inch.	Reduced area. Per cent.	Sample No.	Tensile strain per square inch.	Reduced area. Per cent
	$\frac{3}{8}$ IN. IRON.			$\frac{3}{8}$ IN. IRON.	
124	61 481	30	125	58,653	22
132	60,108	47	131	57,377	15
148[1]	56,270	25	149[1]	54,461	17
	$\frac{1}{4}$ IN. IRON.			$\frac{1}{4}$ IN. IRON.	
128	61,538	36	129	59,125	18
136	58,373	38	135	53,333	9
	$\frac{5}{16}$ IN. IRON.			$\frac{5}{16}$ IN. IRON.	
126	62,871	38	127	58,765	20
134	62,195	43	133	60,202	10
	$\frac{1}{2}$ IN. IRON.			$\frac{1}{2}$ IN. IRON.	
146	61,918	33	147	63,469	6

[1] Samples Nos. 148 and 149 American iron, but of different manufacture from the other samples.

TABLE 2.—*Tests made by Manufacturer.*

With the Grain		Across the Grain.	
Tensile Strain per square inch of Section.	Reduced Area. Per cent.	Tensile Strain per square inch of section.	Reduced Area. Per cent.
$\frac{3}{8}$ IN. IRON.		$\frac{3}{8}$ IN. IRON.	
60,000	44	61,800	22
59,000	42	57,300	13½
$\frac{1}{4}$ IN. IRON.		$\frac{1}{4}$ IN. IRON.	
55,400	34½	52,300	17½
60,100	34	54,600	11
$\frac{5}{16}$ IN. IRON.		$\frac{5}{16}$ IN. IRON.	
57,000	45	56,800	20
63,400	44	55,900	21
$\frac{1}{2}$ IN. IRON.		$\frac{1}{2}$ IN. IRON.	
60,200	31	53,700	6

TABLE 3.—*Tests made in the Treasury Department—English Iron.*

With the Grain.			Across the Grain.		
Sample No.	Strain per square inch of section	Reduced area. Per cent.	Sample No.	Strain per square inch of section.	Reduced area. Per cent.
	$\frac{1}{4}$ IN. IRON.			$\frac{1}{4}$ IN. IRON.	
150	50,555	16	151	40,792	2
152	54,909	13	153	45,334	5
154	56,600	20	155	50,476	8
156	53,061	17	157	54,040	13
158	52,040	10	159	52,575	7

nearly one inch wide. Nos. 126 and 127, $\frac{5}{16}$ iron, were small, and 133 and 134 of the same thickness, were of the larger area. Nos. 146 and 147 were samples of $\frac{1}{2}$ inch iron, cut the square of its thickness. I am particular in this description, for the purpose of illustrating that the change adopted by the Board in its new rules—adopted the past winter—allowing two samples of different areas to be tested, instead of one, as provided for in the old rules, seems to have developed the fact that the manufacturers have gained nothing by the change; the average breaking weight per square inch of section being 59,621 lbs. in the small samples, and 59,818 in the larger ones, showing a difference of only 197 lbs. in favor of the latter. The average breaking weight of the samples cut lengthwise of the fibre or grain is 61,196 lbs. to the square inch, while that cut crosswise of the fibre or grain, shows an average of only 58,703 lbs. to the square inch, a difference in favor of the first, of 2493 lbs. Duplicate samples of the same iron, broken at the manufactory (see Table No. 2), show nearly the same relative results, namely, 59,300 lbs. with the grain, and but 56,050 lbs. across the grain, a difference of 3243 lbs. in favor of the lengthwise cuttings. The iron broken on the scales at the Treasury Department, shows an average of 2271 lbs. greater tensile strain than do those broken on the manufacturer's scales, which fact opens a question as to the correctness of either scale, an important matter when it is to be taken into consideration, that not only pecuniary penalties, but imprisonment is likely to follow false stamping.

Samples numbered 150 to 159, inclusive, are ten samples of English manufacture of various brands showing an average breaking weight of 51,038 pounds to the square inch, with an average reduction of area, in the samples lengthwise of the grain of 15 per cent., while that across the grain was only 5 per cent., showing inferiority to the American iron in every respect,—the latter exhibiting a reduction of 38 and 15 per cent., respectively, lengthwise of and across the fibre, in samples broken at the Treasury Department, and 39 and 15½ per cent., respectively, in the manufacturers' results.

The comparison also illustrates, and almost proves, what I have before alluded to, namely, an error in one or the other of the scales, the uniformity of percentage showing an average inequality in the iron taken from different parts of the same sheet. The difference in the tensile strain must be attributed to defects in the scales of one or both the testing machines used.

The January number of the *London Engineer* contained a report of a series of experiments by Chief Engineer Shock, of the United States Navy, which shows different results from those given here regarding the strength with and across the grain of iron, but the fact that such results are contrary to all former experience, and also to the results here given, would seem to indicate that the iron used by Mr. Shock was of exceptional quality, and that it would be difficult to obtain such results a second time. That being the case, safety would seem to require that boiler-makers should be careful, in working plates into boilers, to see that they are placed so that the greatest strain shall be with the grain of the iron.

Manufacturers would benefit themselves and render valuable assistance to the Board of Supervising Inspectors if they would confer with each other and unite in recommending some standard for determining the lawful qualities of boiler-iron, and submit the same to the Board at its meeting in January next, in order that this body may frame a rule which will make the method of testing iron uniform throughout the United States, thereby protecting themselves as well as the public from the evils of the present system, which makes it possible for an officer who may be prejudiced in his views, to exclude from certain markets certain brands of iron to the injury of the manufacturers thereof, without benefiting the general public.

THE RELATION OF DUCTILITY TO TENSILE STRENGTH IN BOILER-PLATE.

In pursuance of a general call, a convention of boiler-plate manufacturers was held in Philadelphia, November 13th, 1878, and action was taken upon the suggestion of the Supervising Inspector General, contained in the last paragraph of the above paper.

Through the courtesy of Dr. Charles M. Huston, who presided at the meeting, and Mr. W. H. Morris, the secretary, we are able to give the following extract from the proceedings.—Eds.

After some discussion the following resolutions were adopted:

Resolved, That in the judgment of this meeting, plates should not be used in a steamboat boiler, that show a contraction of area less than 12 per cent. We therefore recommend that all boiler-plate, stamped with tensile strain of under 45,000, should show contraction of area of 12 per cent.; 45,000 and under 50,000, should show 15 per cent.

contraction of area; 50,000 tensile strain and under 55,000, 25 per cent.; 55,000 tensile strain and over, should show 35 per cent.

WHEREAS, The question was raised before the meeting of the Board of Supervising Inspectors, at its meeting last January, in regard to the form of test pieces they had adopted, and whereas, the Board, in order to meet the views of the manufacturers, adopted two modes of preparing the test pieces, with a view to ascertain which was right, therefore

Resolved, That the thanks of this meeting be extended to the Board for this act of courtesy, which has resulted in the fact, that there is no practical difference in the two modes.

Resolved, That we respectfully suggest to the Secretary of the Treasury, that test pieces, cut from the plate to be used in steamboat boilers, be all tested, at some central location, by a person appointed by the Secretary of the Treasury, to be under the direction of Supervising Inspector General of Steamboats.

Resolved, That a copy of these resolutions be forwarded to the Supervising Inspector General, duly signed by the President and Secretary.

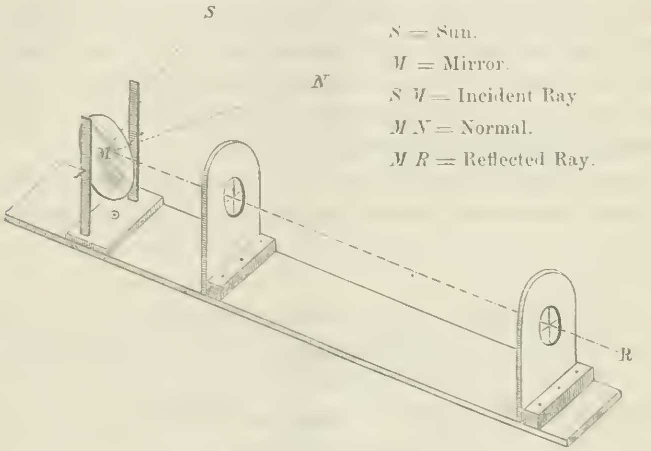
ON THE USE OF THE HELIOTROPE IN GEODETIC SURVEYS.

Contributed by L. M. HAUPT, Professor of Civil Engineering, Towne Scientific School.

The heliotrope is used to reflect the sun's rays to distant points, and thus facilitate the operation of reading angles, either horizontal or vertical, on lines of from 15 to 100 miles in length. The name is derived from *ἥλιος* the sun, and *τροπή* turning—hence the instrument is one which turns or deflects the rays in any required direction. It differs from the heliostat in not being automatic.

Its construction is so simple that it may be made by any schoolboy with a penknife. Two opaque screens are placed about 18 inches apart upon a strip of wood forming a base and screwed or nailed fast. A hole about one inch in diameter should be cut through each screen, the one in rear being a little larger than the other, and across each there should be drawn two fine wires or threads so as to intersect each other.

About six inches in rear of the screens there should be placed a small mirror, 3 inches in diameter will be sufficient, so mounted as to have the two motions horizontal (or in azimuth) and vertical (or in altitude). The crude instrument is then ready for operation. To throw the ray upon any given object visible to the unaided eye, turn the mirror down out of the way or remove it altogether, and sight across the wires, moving the base until the line joining the intersections of the cross wires passes through the object. Then replace the mirror carefully so as not to disturb the line of sight, and turn it in either or both directions until the shadow of the edge of the hole in the first screen is concentric with that in the second. The reflected ray will then be visible to an observer at the given point.



S = Sun.
M = Mirror.
S M = Incident Ray.
M N = Normal.
M R = Reflected Ray.

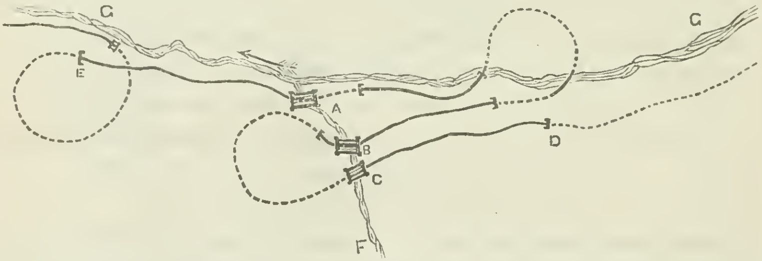
SIMPLEST FORM OF HELIOTROPE.

When the observer is so distant that a telescope is necessary to determine the direction to him, the instrument is modified by attaching the rings and mirror to the telescope, care being taken that the axis of the rings is parallel to that of the instrument. Should the sun be in the plane of the mirror or back of it so that no reflection can be obtained, an auxiliary mirror must be used and placed in such a position as to reflect the ray upon the primary mirror which, by a second reflection, sends it through the rings.

Although so simple and inexpensive, this little instrument serves to increase greatly the economy and accuracy of reading angles to very distant objects. The rays reflected from it are plainly visible to the naked eye at from 30 to 50 miles, and with telescopes these "day stars" have been seen at a distance of nearly 100 miles across Lake Superior when no trace of land was visible.

It needs no second thought to perceive that they may be used as were the semaphores of Claude Chappé introduced in 1794 as the first efficient *telegraph*, but with greater effect. By adopting any convenient code of long and short flashes made by obscuring the ray, messages may be sent from point to point. In one instance a vessel was saved by signaling to a party at Marquette, Lake Superior, that she had grounded on some rocks near the station "Vulcan" on Keweenaw Point.

The Morse code is as convenient as any other, but for simplicity a conventional code expressing certain sentences by a few flashes is found to answer the ordinary requirements of field work.



The St. Gothard Tunnel.—In a private letter written from Geneva, October 1, 1878, to a gentleman of this city, Mr. Walton W. Evans, the eminent consulting engineer, speaks of the St. Gothard tunnel, now in course of construction, as follows: * * "I went over the St. Gothard Railway with the engineer, as far as the big tunnel, to see the most difficult railway works ever attempted in the world; nearly one-third of the whole line is in tunnels. In some places the railway is put in tunnels to get it out of the reach of avalanches; in one case the engineer pointed out to me, as we were riding on the highway, 60 to 70 feet above the river, the place where an avalanche came down last summer, filling the whole valley, and coming up into the road where our carriage was. I will enclose to you a sketch of a piece of the location of this railway, taken from their map. Their fixed maximum gradient is 1 in 40; their fixed minimum radius of curvature is 1000 metres. There are no side valleys to run up and back again to get distance, and as the valley in some places rises faster than the fixed gradient allows, the engineers are forced to tunnel into the sides of the mountains in entire circles (corkscrew circles) to get distance. The sketch I enclose shows three of these circular tunnels, about 8 kilos. north of the big tunnel.

"The waved lines show water-courses, *G G*, being the River Reuss. The full lines show the location of the railway lines, and the dotted lines the tunnels. The points *A*, *B* and *C* show bridges over a cascade. The bridge at *B* is about 500 feet above the bridge at *A*, and the bridge at *C* is about 300 feet above that at *B*. The circles in the tunnels are 2000 metres, or 6502 feet diameter.

"On the south or Italian side of the big tunnel, are more difficult locations still. The roads here are beautiful: built and kept in order by the State. All their work is well done.

"The tunnels of this railway (even the big tunnel is solid granite, and wide enough for three tracks) are arched with granite, but little inferior to the face-work of the Astor House. You can imagine that none but the rich nations of Europe could, for a moment, think of building such a railway.

"I was run into the big tunnel for 2 kilos., on one of their air engines, to see a drilling machine I once explained to you. Baron Lauber tells me it is pressed against the rock with a pressure of 130 atmospheres, and that it walks into granite as if it were cheese."

* * In regard to the abundance of water-power in Switzerland, Mr. Evans says: "There is a tremendous water-power going to waste all over Switzerland; you can see in hundreds of places streams of water coming down nearly perpendicular for 1000 or 2000 feet. At the great tunnel of the St. Gothard Railway, the River Reuss crosses the very mouth of the tunnel, and gives the engineers a water-power fifty times greater than they can use for compressing air, making repairs, etc., etc." * * S.

Automatic Switch for the Jablochkoff Candle.—Jablochkoff has introduced a new automatic switch in his lamps. A bell crank lever has a platinum rod at one end, which is pressed by a spring against the isolating mass between the two carbons. As soon as the candle burns below this point, the spring throws the lever over; the current passes through the other arm of the lever, which becomes part of the circuit, to the second candle; and a new one may be substituted for the first.—*Journal für Gasbeleuchtung*, etc. P.

The Determination of Carbonic Acid in Air to be Breathed.[1] —Dr. Pettenkofer, of Munich, has found that carbonic acid accumulates in a room in almost the same ratio as impurities resulting from breathing and other exhalations from human beings. The percentage of carbonic acid consequently indicates the degree of impurity, provided the gas is not generated artificially. Atmospheric air contains about $\frac{4}{10}$ volumes per mille. Dr. Pettenkofer places the extreme limit of admixture of good air for breathing in a room at 1 per mille.

In imperfectly ventilated schoolrooms it has been found as high as 10 per mille.

Dr. Pettenkofer found that the air of a room of 75 cubic metres contents, all windows and doors being closed, was entirely renewed each hour; and that after hermetically closing door and window cracks, it still continued at the rate of $\frac{3}{4}$ the volume of the room per hour. This was with an outside temperature of — 1° (most probably Centigrade) and + 18° in the room—consequently a difference of 19°. This must take place through the pores of the walls.

To determine the renewal of the air, he made use of the admixture of known quantities of carbonic acid. He allowed the gas to enter the room; it diffuses itself through the air. A chemical analysis of the air then indicates how rapidly the new air passes in, for as soon as the percentage sinks to the normal quantity of ordinary atmospheric air, the whole volume has evidently been replaced. The time in which this takes place gives an approximate estimate of the rapidity with which the outer air enters.

Experiments made in France about thirty years ago, showed that about 60 cubic metres of fresh air per person were needed each hour, in order that no offensive odors should arise in a crowded room. Dr. Pettenkofer arrives at the same result by chemically analyzing the air and measuring the percentage of carbonic acid, then determining the quantity of fresh air necessary to keep it within 1 per mille in a room full of people. This quantity is very large, as only $\frac{1}{2}$ cubic meter is needed for breathing by each adult per hour. But the impurities are rapidly diffused through the air, and render it unfit for breathing.

---

[1] From a paper read by F. Paul, Engineer, at the meeting of the Austrian Society of Engineers and Architects, February 14th and April 11th, 1878, and published in No. IX of their journal.

According to Dr. Pettenkofer the best French authorities give the following quantities of pure air as necessary, per hour, for each individual:

In hospitals (ordinary invalids),	60–70	cubic metres.
“ (for the wounded),	100	“
“ (epidemic diseases),	150	“
In prisons,	50	“
In workshops (ordinary),	60	“
“ (in unhealthy locations),	100	“
In barracks (by day),	30	“
“ (by night),	40–50	“
In theatres,	40–50	“
In halls (for long sessions),	60	“
“ (for short sessions),	30	“
In schools (for children),	12–15	“
“ (for adults),	25–30	“

P.

Electric Lighting.—In reviewing the present state of electric lighting, the *Journal für Gasbeleuchtung*, etc., says:

Its practical utility as an illuminating agent has only been acknowledged since means have been discovered, 1st, to generate the electric current at a relatively low cost; 2d, to produce an almost constant light; 3d, to subdivide the light.

The first decisive step towards giving the electric light its present undeniable importance, was the substitution of the magneto-electric and dynamo-electric machines for galvanic batteries.

Owing to the more rapid and irregular wasting of the positive carbon pencil, different mechanical arrangements were designed to keep the points at a constant distance from each other. Serrin's lamp has been principally used, till last year, when Jablochkoff gave a new complexion to the whole subject by his invention. He places the carbons beside each other, and isolates them with a mass, solid at ordinary temperatures, but fusing at such as are necessary for the production of the voltaic arc, and becoming then a good conductor. Powdered glass and kaolin have been used for this purpose, but lately other preparations have been substituted, partly to render the color of the light more agreeable, partly to obtain greater steadiness.

This property of the isolating mass enables the current to be subdivided. Besides, the improved machines can also generate several currents, so that each may be used to operate several lamps.

For instance: the 48 lamps which illuminate the Avenue and Place de l'Opera, Paris, are operated by three machines, each furnishing four independent currents, and each of the latter feeding a group of four lamps. Each lamp has four carbon candles on a turn-table, so that when one wastes away (in about 1½ hours, the machine working uniformly) a new one can be placed in position by turning a crank. The whole arrangement is enclosed by thick ground glass. To ignite the carbon, a piece is laid on top, which is rapidly consumed.

The copper wires from the machines are covered with gutta-percha, carried underground through earthenware pipes, and isolated every half-metre by the supports. Four wires run from each of these main wires to each of the four carbon pencils of a lamp; the current then is led by a single wire to the next lamp, then to the third, to the fourth, and finally back to the machine.

The lamps operate 6 hours, when gas is substituted. At least one horse-power is regarded as necessary to operate a lamp. Its intensity is considered as equal to that of 100 gas-jets (each consuming 105 litres per hour). But this is only partly true, as the gas-flames must be regarded as concentrated at one point. If a given enclosure is illuminated by a number of gas-jets, and then by the electric lamp, the latter cannot replace more than 30 jets; generally less—between 20 and 30.

A great advantage is the almost complete immunity from danger of fire and the small quantity of heat evolved.

The city of Paris pays 1 fr. 45 c. per hour for each lamp, which nominally gives a light of an intensity of 100 gas-jets. The scientific journals, however, state that the real intensity is equal to no more than 20 jets, with a total consumption of 2·8 cubic metres per hour.

Further taking into account that two main wires must be laid to each lamp, with four branch wires; that every 1½ hours a new carbon candle must be brought into position by hand; further, that one machine, requiring one horse-power, is needed for every four lamps, and cannot be placed at one centre with others, as it is impracticable; and finally, the unreliable nature of the steam motive-power which generates the light; no one will seriously think that street-lighting can at present be accomplished.

For lighthouses, large open squares, workshops, depots, theatres, and large halls, it may be adapted, and in those cases it will compete with gas. P.

A Novel and Simple Method of taking Specific Gravities.—M. Gannal has recently devised a means of determining exactly, and with the greatest facility, the specific gravity of all liquids.

With his "*densimetre hydrostatique*" all calculation is obviated, and the specific gravity is ascertained by simply reading the weight on the balance.

This useful and ingenious apparatus is made in the form of an *olive*, so that bubbles of air shall not attach themselves to its sides. The olive (whether made of glass or metal) has a volume exactly equal to one decimal subdivision of a cubic metre. There are two different methods employed in the practical use of the apparatus:

1st. We may suspend it on the platform of the balance, and after having produced an equilibrium we plunge it into the liquid, the equilibrium is then destroyed by the loss of weight of the olive, and the number of grammes which it is necessary to add to the scale pan to restore the equilibrium, is the exact specific gravity of the liquid.

2d. Or we may equally well adopt the following plan: We put the liquid whose specific gravity we desire to ascertain, in a glass vessel on one pan of the balance; we balance the scale pans, and then suspend the olive in the liquid by means of a fine thread. The equilibrium is destroyed, and the scale descends on the side on which the olive is suspended, and the weight—which it is necessary to place in the other pan to restore the equilibrium—is equal to the specific gravity of the liquid.

This apparatus will determine the density of all liquids whether they be heavier or lighter than water, whether they be acids, alcoholics, thick or syrupy. It advantageously supersedes the areometers: it is not fragile, and it gives the indications with an exactitude depending on the sensibility of the balance employed. The work is reduced to a simple weighing and reading of the weights on the balance.

M. A. Gannal has constructed instruments of 100 cubic centimetres, and 10 cubic centimetres only. The larger apparatus is the one which will prove the most convenient and the most needed in commercial and industrial determinations. With this instrument, and a balance sensitive to one decigramme, we may determine the density to the thousandth degree.—*Les Mondes*, Sept. 26th, 1878.

O.

Transit of Mercury, at Rio Janeiro.—Dom Pedro was one of the observers of the late transit of Mercury, at the Imperial Observatory of Rio Janeiro. The contacts were perceived and noted simultaneously by the Emperor and all of the other observers. Liais's new method was employed, and the result differed from calculation by less than $\frac{1}{5}$ of one per cent. in right ascension, and by only $\frac{1}{10}$ of one per cent. in declination.—*Comptes Rendus.* C.

New Laws of Expansion.—M. M. Levy deduces from the two fundamental propositions of thermo-dynamics, the following corollaries: 1. The internal heat of a body cannot be any single function of the specific volume and of the temperature of that body; it can only be the sum of two functions; one of the volume alone, the other of the temperature alone. 2. The same thing is true of the quantity which Clausius has designated as the *entropy.* 3. Hence, the pressure which any body supports, so long as the body does not change its state, can be only a linear function of its temperature; in other words, if any body whatever is heated, under constant volume, the pressure which it exerts on the immovable walls of its enclosure can increase only in proportion to its temperature.—*Comptes Rendus.* C.

Amber Varnish.—S. Meredith prepares a varnish which gives a very fine polish, and which is especially valuable for carriages and for choice furniture. He puts 7 pounds of amber in a clay crucible, with 14 pounds of rock salt, adding water enough to dissolve the salt. He then adds more water, and keeps the crucible over a fire until the amber becomes perfectly white. The bleached amber is put into an iron pot, and warmed over an ordinary fire until it is completely dissolved; the pot is then allowed to cool, and the amber is placed in a stream of water, to remove the salt; it is then reheated until it dissolves, when it is poured on a marble table to evaporate the water, and then exposed to a greater heat to drive off all moisture. This bleached amber is powdered, and then melted in an iron pot. Fine nut oil is added, and stirred until the mixture is complete. The pot is then removed from the fire, and, when sufficiently cool, spirits of turpentine is added to produce the proper consistency. The following proportions are recommended: White amber, 1 lb.; fine nut oil, 1lb.; spirits of turpentine, 2 lbs.—*Les Mondes.* C.

Koerting Blowers.—A. Scheurer-Kestner has reported some experiments with Koerting blowers under various conditions of temperature and pressure. The greater the pressure in the generator, the greater is the useful effect of the vapor. In one experiment, with a boiler pressure of 5 kilogrammes (11·02 lbs.), temperature of the gaseous mixture 31·1° (88° F.), temperature of surrounding air 22·3° (72·1° F.), 8·6 per cent. of vapor carried 91·4 per cent. of air.—*Bull. de la Soc. Ind.* C.

Scientific Skepticism.—M. Bouillaud finds it so difficult to accept the ordinary explanations of the phonograph and the telephone, that he propounds some new and curious hypotheses. He asks whether it is really the phonograph that repeats the sound; whether the repetition is not due either to some kind of echo, or to unconscious action in the vocal organs of the bystanders; and whether the telephone does not act simply as a good conductor of sound, independently of any electric currents.—*Comptes Rendus.*
C.

Paper-Sizing.—C. Wurster, in a prize memoir, recommends the use of a preparation of soda and resin, in such proportions that some of the latter material may remain uncombined, so as to have a solution of resin in resin-soap. If this preparation is diluted with water, it forms a milky liquid, which owes its appearance to the resin that is suspended in a state of extreme division. It is especially important, before adding alum, to have the greatest possible quantity of free resin, because the quantity of fibre which the sizing will cover is proportional to the minuteness of the impalpable particles.—*Bull. de la Soc. Ind.*
C.

Wood-Staining.—Wood may be stained *brown* by a concentrated aqueous solution of permanganate of potash; *red:* boil ¼ lb. of logwood and ½ oz. of soda, in 1 pt. of water; apply it hot, and then wash it over with a strong aqueous solution of alum; *rose:* iodide of potash in 12 parts of water for a first coat, and corrosive sublimate in 40 parts of water for a second; *blue:* indigo solution, or a concentrated hot solution of blue vitriol, followed by a dip in a solution of washing soda; *yellow:* turmeric, dissolved in wood-naphtha, or aqua regia in 3 parts of water; *green:* verdigris, dissolved in 4 parts of water.—*Fortsch. d. Zeit.* C.

Pocket Microphone.—M. Trouvé has invented a cylindrical microphone, which resembles a small dark-lantern, with a carbon crayon substituted for the candle. When placed in the middle of a room, it reveals all secrets. It transmits the voice admirably to a receiving telephone, even when the speaker stands 25 metres (82 ft.) or more from the microphone. When a watch is placed in the interior, it seems to be making unheard-of efforts to get out. The instrument can be easily used for revealing the normal or morbid movements of the heart or lungs.—*La Nature.* C.

Phonic Wheel.—P. Lacour has devised a toothed wheel of soft iron, which turns on its axis so that its teeth pass near one pole of an electro-magnet without touching it. An intermitting electric current, regulated by the vibrations of a reed or tuning-fork, traverses the coils of the magnet, so that it periodically attracts the nearest tooth. The wheel, turning with such velocity as to traverse the space between two teeth at each period of the current, maintains a uniform movement. It is well-fitted for use as a chronograph, for finding the number of vibrations in a given musical note, and for establishing synchronism in telegraphy.—*Comptes Rendus.* C.

New Telephonic Transmitter.—P. Dumont combines a thread telephone, with a carbon-electric microphone. A parchment membrane, 12 centimetres (4·7 inches) in diameter, is stretched over a vertical frame. At the centre a thread is fastened by a knot at one end, the other end passing over a small pulley, and supporting at its lower extremity a brass cone, suspended by a hook fixed in the centre of its base. This cone, weighing 20 grammes (308·65 grains), penetrates by its point to a depth of about 1 millimetre, into a metallic die filled with dust of gas-carbon, and fixed on the horizontal base which supports the diaphragm-frame. One of the poles of the battery (four Leclanché elements) communicates with the metallic cone, the other with the die. The least variations impressed on the membrane by the sound-waves modify, by the intervention of the pulley, the pressure of the cone on the carbon-dust, and thus produce variations in the intensity of the current, followed by a distinct reproduction of all the sounds in a receiving telephone.—*Comptes Rendus.*

C.

Solidification of Petroleum.—Even the lightest petroleums may be partially solidified, by mixing them with an aqueous decoction of soapwort. A mucilage forms, which is so thick that the containing vessel can be overturned without any portion running out. If a few drops of phenic acid are stirred into the mucilage, it soon becomes liquid again.—*La Nature.* C.

Signals for Daltonists.—M. Dherbes, who is himself afflicted with Daltonism, finds no difficulty in distinguishing the following colors. when they are distinctly marked: Sky-blue, bright yellow, scarlet. He therefore proposes the adoption of those tints for luminous signals, or the employment of signals of different forms, *e. g.*, square, triangular, circular, etc.—*Comptes Rendus.* C.

Mean Distance of Water Molecules.—In connection with electrical investigations, Hermann Herwig has made an extended series of observations, with a view of obtaining a nearer approximation to molecular distances in fluids. He concludes that no two molecular layers in water can be more than 1·86 of a millionth of a milimetre apart, and that the same is true with regard to the mean distances of adjacent molecular centres. Sir Wm. Thomson had previously estimated the least value of the same distances at ·05 millionths of a milimetre. These two estimates, one being less than four-fold the other, furnish satisfactory approximations to the true value.—*Ann. der Phys. u. Chem.* C.

Daily Shifting of Levels.—During the past spring Plantamour was induced to make some observations upon the displacement of the bubble in spirit-levels, and he found that there was a daily maximum during the afternoon, accompanied by gradual changes, which extended over a period of several successive days. In confirmation of his observations, M. d'Abbadie reported his own experience at Olinda, Brazil, in 1837; at Gondar, Ethiopia, in 1842; and subsequently, at Saqa. At each of these places the bubbles of the levels showed small variations in the direction of the plumb-line. Astronomers have, doubtless, often suffered from these changes, without being aware of their cause, and have been obliged to mask them by taking the means of frequent observations.—*Comptes Rendus.*

C.

Electric Light in Farming.—M. Albaret has invented an apparatus for the application of electric light to agricultural labors. A portable engine, of 4 or 5 horse-power, carries a mast, 20 or 25 metres (65·6 or 82 ft.) high, and drives a Gramme machine. The electricity is conducted to the regulator of the light, in a lantern at the top of the mast. The mast, which is composed of numerous iron tubes, is raised or lowered at pleasure by a winch at its base. The lantern is connected with pulleys, so that it can be brought down without lowering the mast.—*Les Mondes.* C.

Optical Thermometer.—Fizeau, de Lang and Sohncke have experimented on the rotatory power of quartz, between 0° and 100° (32° and 212° F.). Joubert has extended the investigation from — 20° to about 1500° (— 4° to 2732° F.). He finds the law of angular deviation so simple that he recommends quartz as a very simple thermometer and one that especially satisfies the essential condition for every thermometer, comparability. When the apparatus is once prepared, the simple reading of an angle and the employment of a table, which has been calculated once for all, give the temperature.—*Comptes Rendus.* C.

Postal Items.—The number of letters mailed annually, is estimated at 4000 millions. The German post-offices alone delivers 300 millions in a year. Wax tablets are first mentioned in the sixth book of the Iliad. The Egyptian papyrus was, for a long time, very dear. In the time of Pericles a medium-sized sheet cost $1.50. Parchment was introduced in the 3d century B. C.; paper was made from rags in Italy, A. D., 1314. The first German paper-mill was erected at Mainz. Letters assumed their present form in the 14th century. Envelopes were invented in 1820. In 1866, Dr. Stephan invented the postal card, of which 400 millions are now annually used in Europe. Cyrus established the first horse mail. Carrier-pigeons were first used in the East. Rome used private letter-carriers in the time of the Republic. Letters from Africa required 15 to 20 days; from Asia, 40 days. Augustus established the first public mail. The mail-messengers were called *equites positi*, hence the name "post." The German-Austrian postal union began in 1850. The world's postal union now embraces 20 million square miles of territory.—*Dingler's Journal.* C.

Franklin Institute.

HALL OF THE INSTITUTE, Nov. 20th, 1878.

The stated meeting was called to order at 8 o'clock P. M., the President, Dr. R. E. Rogers, in the chair.

There were present 138 members and 51 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting there were 11 persons elected members of the Institute, and the following donations to the Library were reported:

British Patent Specifications and Drawings, Nos. 1584 and 1779, and Vols. 21–45, 1877.

British Patent Abridgments relating to Paper, etc., Part 2, 1859; Tea, Coffee, etc , 1704–1866; Chains, Chain Cables, etc., 1867–1876; Dressing and Finishing Woven Fabrics, 1620–1866.

British Patents. Alphabetical Index for 1876.

British Patents. Disclaimers, Nos. 336, 1869; 161, 1870; 2397, 1871; 1527, 2456, 1872; 412, 599, 2171, 1875; 828, 977, 1339, 2764, 4499, 4553, 4746, 5064, 1876; 1860, 3096, 1877.

From Commissioners of Patents, London.

Instructions to Meteorological Observers in India, by H. F. Blanford, Calcutta, 1876.

Tables (5) of Meteorological Results at the Observatories.

Tables for the Reduction of Meteorological Observations in India, by H. F. Blanford, Calcutta, 1876.

Meteorology of Bombay Presidency, by Chas. Chambers, London, 1878.

Meteorology of Bombay Presidency, Diagrams and Maps.

From Meteorological Department, Calcutta, India.

Catalogue of the Library United States Patent Office, Washington, 1878.

Annual Report of the Commissioner of Patents for 1877, containing Index to Official Gazette for 1877. Washington, 1878.

Index to Official Gazette for January to June, 1878. Washington, 1878.

Specifications and Drawings of Patents, for April and May, 1878. Washington, 1878. From Hon. Commissioner of Patents.

American Ephemeris and Nautical Almanac for 1881.

From Secretary of Navy.

Lecons Cliniques sur les Maladies du Cœur, par P. F. DeCosta Alvarenga, Lisbonne, 1878.

Journal de Sciencias, Mathematicas, Physicas e Natureas, Nos. 21 and 22. From Royal Academy of Science, Lisbonne, Portugal.

Annual Report of the Chief Engineer of the Water Department of Philadelphia for 1877. From W. H. McFadden, Chief Engineer.

Historical Map of Pennsylvania. Edited by P. W. Sheafer, Philadelphia, 1875. From the Historical Society of Pennsylvania.

Report on the Meteorological Service of the Dominion of Canada for 1877. Ottawa, 1878. From the Meteorological Department.

Directory to the Iron and Steel Works of the United States. September 1st, 1878.
From American Iron and Steel Association, Philadelphia.

Report of Prof. A. D. Bache, showing the progress of Coast Survey work for the year 1849.

Patten's Artillery Drill. N. Y., 1863.

Memoir of Quamino Buccau, by W. J. Allinson. Philad'a.

Chemistry in its application to agriculture and physiology, by J. Liebig. Philad'a, 1843.

Map of the State of New York. Published by S. A. Mitchell. Philad'a, 1831. From D. S. Holman.

Fonetic Magazine, devoted to the interests of education. Edited by E & S. Longli. London, 1848–50. Vols. 1 and 2.

Phonetic Journal, for 1850 and 1852. Vols. 9 and 10.

Phonotypic Journal, 1843 and 1845. London. Vols. 3 and 4.
From H. T. Child.

Industrial Progress of New South Wales. Sydney, 1871.

Financial Statement of Hon. H. E. Cohen, Treasurer of New South Wales. Sydney, 1878.

Journal and Proceedings of Royal Society of New South Wales. Vol. 11. Sydney, 1878.

Remarks on the sedimentary formations of New South Wales, by W. B. Clarke. Sydney, 1878.

Climate of New South Wales, by H. C. Russell. Sydney, 1877.

Essay of New South Wales, by G. H. Reid. Sydney, 1878.

Annual report of Department of Mines of New South Wales, for 1877. Sydney, 1878.

Railways of New South Wales, by John Rae. Sydney, 1877.

Statistical register of New South Wales, for 1876. Sydney, 1877.

Mineral Map, Pastoral District Map, and Agricultural Map of New South Wales. From R. S. Menamin.

Quarterly report of Chief of Bureau of Statistics. Treas. Dept. Washington, 1878. From Chief of Bureau.

Mr. Chas. M. DuPuy read a second paper on his direct process of making wrought-iron.[i] An interesting discussion followed the reading of the paper, participated in by Messrs. Orr, Loiseau, Jenks, Ware, Pemberton, and the President, during which Mr. DuPuy drew on the blackboard a sketch of the furnace used in connection with his process.

Dr. Isaac Norris, Jr. read a short account of the continuation of his experiments with the microphone, and especially in adapting it to the stethoscope; and exhibited an instrument of this description which had been received with considerable favor by the College of Physicians in this city.

This instrument is in the form of the ordinary Bell telephone, but has the magnet and coil replaced by a metallic tube which can be adjusted endwise by means of the screw at the end of the handle. This tube has a small carbon cup inserted in the end towards the diaphragm.

To the centre of the inner side of the diaphragm is soldered another short tube, also carrying a carbon cup. Each of these tubes is connected by a wire to binding-posts. The two carbon cups are placed about half an inch apart, and a pointed stick of carbon rests lightly in them, thus completing the circuit with a Bell telephone.

This instrument is exceedingly delicate, but has the disadvantage of not working well in all positions.

In the first form of this instrument the carbon in the movable tubes was made pointed, and adjusted to touch very lightly the plane surface of the carbon on the diaphragm, but this was found to require too delicate and frequent adjustment, and was therefore abandoned.

In still another form, a combination of three sets of carbons were employed, but with less satisfactory results than with the single one.

The Secretary's report embraced the Otto Silent Gas Engine,[ii] Moses Burpee's Automatic Car-Coupling; Mrs. M. E. Beasley's Steam Meat Roaster; A. T. Cross' Fountain (stylographic) Pin; and The Organette or Domestic Organ.

The organette consists of a series of reeds placed in suitable passages formed in a block of wood, the inlets being from the under side. These passages are placed over corresponding passages or openings in the top of a wind-chest, supplied by three small bellows operated by a triple crank-shaft. A sheet of paper of sufficient width to cover all the passages, has cut through it, openings of such length and distance apart as to correspond to the length and interval between the notes of a tune, when the paper is moved at a rate of speed previously determined upon: the position of the openings in relation to the width of the paper, determining the note or reed to be sounded. The sheet of paper thus perforated, is a perfect graphic representation of the music—the length of the hole representing the length of the note: the space between them, in the same line, representing the interval; and the position, as to the width of the paper, the pitch. The sheet of paper having been properly perforated, has its ends pasted together, forming an endless band, and is drawn along by means of suitable rollers, between the top of the wind-chest and the bottom of the reed-chest, and as each opening in the paper is brought to coincide with the passage from the wind-chest to the reeds, the corresponding note is sounded.

---

[i] See page 404 ante.

[ii] A full illustrated description of this engine will shortly be published in the JOURNAL.

The sheets of music are inexpensive, and can be easily and quickly changed.

The whole instrument occupies a space of about 18 inches long, 13 inches wide and 8 inches high.

The Secretary presented and explained the memorial of the Engineers' Club of Philadelphia, to the Legislature of the State, asking for the enactment of "such laws as will provide for a thorough Geodetic Survey of the State, and an accurate and permanent location of all county and township lines;" when, on motion of Mr. J. E. Mitchell, it was

Resolved, That in view of the importance of a thorough Geodetic Survey of the State, the Franklin Institute joins in the petition that the Legislature will provide for its prosecution and completion at the earliest practicable time.

Mr. C. S. Close called the attention of the meeting to the death of Mr. Thos. H. Powers, one of the oldest life members of the Institute, which occurred at eight o'clock this morning; when, on motion, it was

Resolved, That a committee of three be appointed by the chair, to draft a suitable minute and resolutions upon the decease of Mr. Powers, to be presented at the next meeting.

On motion, the meeting adjourned.

J. B. Knight, *Secretary*.

T
1
F8
v.106

~~Physical & Applied Sci. Serials~~

Engineering

Franklin Institute,
Philadelphia
Journal

PLEASE DO NOT REMOVE
CARDS OR SLIPS FROM THIS POCKET

UNIVERSITY OF TORONTO LIBRARY

ENGIN STORAGE